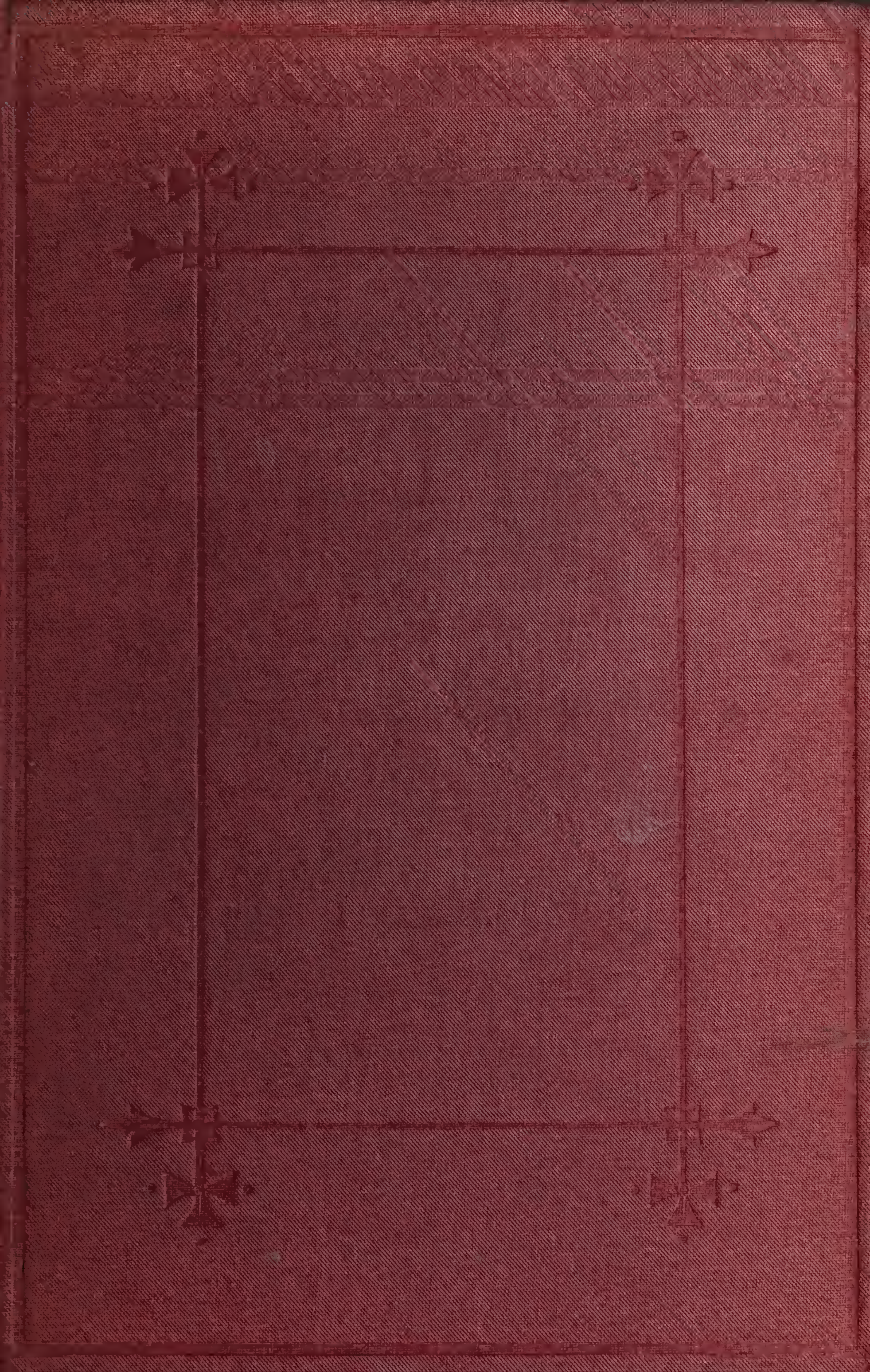

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OR

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IN THE

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DISTRIBUTION OF PLANTS

FOURTH EDITION

By J. H. BALFOUR, A.M., M.D.
LL.D. Glasg. & Edin., F.R.SS.L. & E., F.L.S., F.R.C.S.E.
EMERITUS PROFESSOR OF MEDICINE AND BOTANY IN THE UNIVERSITY
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WITH UPWARDS OF 260 ILLUSTRATIONS

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ST JAMES SQUARE.

TO THE

REVEREND D. T. K. DRUMMOND, B.A.,

INCUMBENT OF ST THOMAS'S ENGLISH EPISCOPAL CHAPEL, EDINBURGH.

My dear Friend,—It is to me a source of peculiar pleasure to be permitted to dedicate this little work to you. There is no one to whom I could do so with higher satisfaction, whether I take into account the deep obligations under which I lie to you, in the providence of God, as a faithful minister of the Gospel, or the affection which I entertain towards you as an esteemed and valued friend.

You have often encouraged me to undertake such a work as the present, and have pressed upon me the importance of prosecuting science in a Bible spirit. During the occasional botanical walks in which we have taken sweet counsel together, your Scriptural views of science have been impressed upon my mind; and I hope, in the short sketches which are now placed before you, there is evidence that your kind suggestions have not been unheeded.

The sketches are very imperfect. They have been drawn up at a time when I had many other occupations to engage my attention; and they call for much indulgence. If they are blessed in any way in promoting the cause of Truth, I shall feel that my labour has not been in vain.

That you may be long spared to fill that useful station which you now occupy, and that you may be the honoured instrument, in the hand of God's Spirit, of proclaiming the Truth as it is in Jesus, and of turning many from darkness unto light, and from the power of Satan unto God, is the earnest prayer of

Your affectionate friend,

J. H. BALFOUR.

PREFACE TO THE FIRST EDITION.

THE subjects embraced in the present volume formed the substance of Introductory Lectures on Botany, which I delivered on more than one occasion to a popular audience. The Rev. Dr King, who attended one of these courses of lectures, urged upon me the propriety of putting my notes into a state fit for publication; and when he undertook the first volume of the " Christian Athenæum," he kindly asked me to unite with him in forwarding the cause of religion and science by contributing a botanical volume. To this I was also stirred up by the advice tendered to me by the late Rev. Edward Bickersteth, who entered warmly into the plan of the work. Yielding to these solicitations, I undertook the task, and I feel that in doing so I have placed myself in a position of great responsibility. I am fully sensible of the imperfect nature of this attempt to illustrate the works of God in the economy of vegetation; but I trust that it may be the means of leading others to take an interest in a science, in the prosecution of which I have spent many pleasant hours,—a science which does not consist, as many suppose, in the mere naming of plants, but which has a higher and a more philosophical aim.

I have endeavoured to add to the value of the work by giving numerous woodcuts derived from original sources, as well as from the works of Maout, Jussieu, St Hilaire, Dutrochet, and others; and I have to acknowledge my obligations to the Messrs Blackie, for allowing me to get impressions from some of the cuts of their Imperial Dictionary.

PREFACE TO THE THIRD EDITION.

The present edition has been much enlarged. A number of new facts in regard to the structure and physiology of plants have been added; the geographical distribution of plants has been more fully dwelt upon; and a chapter has been inserted on the principles of natural classification. The number of woodcuts has likewise been increased. It is hoped that the work will thus be both fitted for the purpose of serving as a popular introduction to Botany, and at the same time for directing attention to some of the wonderful adaptations in the vegetable kingdom. The special object in view has been to bring under the notice of the young some interesting facts connected with the form, structure, functions, and arrangement of plants; and to induce them to enter upon the study of a science which is well fitted for mental culture and training, and is calculated to afford both pleasure and instruction—a science, moreover, which, when properly pursued, leads to elevated ideas of the power and wisdom of the Almighty Creator. The relation between the Word and the works of God, and the light which they mutually throw on each other, are prominently brought forward; and an attempt is made to point out the value of science as a handmaid of religion.

> "Great universal Cause, mysterious Power
> That clothes the forest, and that paints the flower,
> Bids the fell poison in the upas grow,
> And sweet nutrition in the maple flow;
> Where'er we turn, the impartial eye must see
> Each leaf a volume,—its great Author, Thee;
> Nor less in every twig than Aaron's rod,
> Behold the agency of nature's God!"

PREFACE TO THE FOURTH EDITION.

This is simply another issue of the Third Edition, which had been out of print for some time.

I hope that it will be useful to those who desire to possess a knowledge of Botany, and who, at the same time, will take pleasure in the study of plants which are interesting in a Bible point of view.

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BOTANY AND RELIGION.

INTRODUCTORY REMARKS.

THE attention of all who are interested in the wellbeing of mankind has been recently much directed to the subject of education. Schools of various kinds have been established, philosophical and mechanics' institutions have been formed, and men well versed in literature and science have eagerly availed themselves of the opportunities thus presented of diffusing information among the people. The poorest working man of the present day has thus within his power the means of acquiring knowledge. How important is it that such knowledge should be solid and substantial,—not "science falsely so called, which some professing, have erred concerning the faith" (1 Tim. vi. 20, 21), nor the "perverse disputings of men of corrupt minds and destitute of the truth" (1 Tim. vi. 5), who erroneously view reason as opposed to revelation. If the fountains are poisoned, it is not to be expected that those who drink at them will be sound and healthy. Instances are, it is to be feared, not uncommon of parties who, by the acquisition of unsanctified scientific information, have been led into the depths of infidelity and pantheism; making their very knowledge the means of perverting others, and of throwing ridicule and contempt on everything relating to man's fallen condition and God's glorious plan of salvation.

The question then is, How is education to be prosecuted, so as to promote the true welfare of the people? Undoubtedly this can only be accomplished by regarding man, not merely in his relation to time, but in his relation to eternity. Our view must not be confined to his temporary condition on earth, but it must extend to his eternal destinies beyond death and the grave. Hence it is that all attempts to separate secular from religious knowledge are vain and futile. Secular knowledge, as regards itself, is fleeting and evanescent, and will be swallowed up by one glimpse of the glories of eternity. It may and does exalt the pride of human intellect; it renders poor man proud of his attainments; it makes him think himself something, when, in reality, he is nothing (Gal. vi. 3); "it is a knowledge which puffeth up" (2 Cor. viii. 1), an airy nothing, which does not edify nor build up on a solid foundation. It may tell us of a great First Cause, of a God of power and might, but it reveals to us nothing of His character as a God of holiness and purity, and at the same time a God of salvation. It spoils man, as St Paul says, "through philosophy and vain deceit, after the traditions of men, after the rudiments of the world, and not after Christ, in whom dwelleth all the fulness of the Godhead bodily" (Col. ii. 8, 9). Human intellect becomes an idol, and is worshipped independently of Him who lighteth every one that cometh into the world. Ryle, in one of his excellent tracts, says, "It is not atheism I fear so much in the present time as pantheism. It is not the system which says nothing is true, so much as the system which says everything is true. It is not the system which says there is no Saviour, so much as the system which says there are many saviours, and many ways to peace." In another place the same author remarks:—"A man may have prodigious learning, and yet never be saved. He may be master of half the languages spoken round the globe. He may be acquainted with the highest and deepest things in heaven and earth. He may have read books till he is like a walking encyclopædia. He may be familiar with the stars of heaven,—the birds of the air, the beasts of the earth, and the fishes of the sea. He may be able to speak of plants, from the cedar of Lebanon to the hyssop that grows out of the wall. He may be able to discourse of all the secrets of fire, air, earth, and water; and yet, if he dies ignorant of Bible truths, he dies a miserable man. Chemistry never silenced a guilty conscience,—mathematics never healed a broken heart,—all the sciences in the world never smoothed down a dying pillow. No earthly philosophy ever supplied hope in death. No natural theology ever gave peace in the prospect of meeting a Holy God. All these things are of the earth earthy, and can never raise a man above the earth's level. They may enable a man to strut and fret his little season here below with a more dignified gait than his fellow-mortal, but they can never give him wings and enable him to soar towards heaven. He that has the largest share of them will find at length, that without Bible knowledge he has got no lasting possession. Death will make an end of all his attainments, and after death they will do him no good at all."

How singular it is to observe, that men who rejoice in the study of God's works yet in many cases ignore His Word, and turn the very gifts of the Creator into weapons of rebellion. They use the trees of God's garden to conceal Him from their view. "They become vain in their imaginations, and their foolish heart is darkened. Professing themselves to be wise they become fools" (Rom. i. 21, 22). The philosophers of Greece and Rome, notwithstanding all their worldly wisdom, sunk into the lowest depths of iniquity, as fully portrayed by St Paul in the first chapter of his Epistle to the Romans. Such earthly knowledge has no power to renovate the heart. This is true of mere secular education without religion. And yet, in spite of this, there are men who now-a-days advocate the doctrine that science and literature in themselves promote man's moral well-being, and who repudiate the teaching of Bible lessons in our schools. It ought ever to be borne in mind, that there can be no true civilisation without God's Word. One of the greatest monsters in the late Indian outbreak had received a liberal education, and had mingled in all the civilities of British life in India.

"What," exclaims Mr James, "are the loftiest and noblest of the sciences,—Chemistry, with its beautiful combinations and affinities; or astronomy, with its astounding numbers, magnitudes, distances, and revolutions of worlds; or geology, with its marvellous and incalculable dates of bygone millions of ages—to the truth of Revelation? What is dead, inert matter,—with its laws of materiality, however diversified, classified, or combined,—compared with the world of mind, of souls, of immateriality and immortality, and with the laws of moral truth by which they are regulated? What is nature to the God of nature? What is the heavens and the earth to the glorious mind that looks out upon them through the organ of vision, as from a window that commands the grand and boundless prospect? What the fleeting time of man's existence upon earth, with its little cycles of care, and sorrow, and labour, compared with the eternal ages through which the soul holds on her course of deathless existence? The works of creation are a dim and twilight manifestation of God's nature compared with the grander and more perfect medium of redemption?"

Do we then despise secular knowledge? Certainly not. We know that, when properly acquired, it is of the greatest importance. But we desire that it should be sanctified by God's Spirit,—that the contemplation of the various works of God in creation and providence should be made subservient to the advancement of the kingdom of grace,—that they should be studied in the light of God's Word, and thus be made to promote His glory and our everlasting happiness.

> "The desire which tends to know
> The works of God, thereby to glorify
> The great Workmaster, leads to no excess
> That reaches blame, but rather merits praise
> The more it seems excess ;
> For wonderful, indeed, are all His works,
> Pleasant to know, and worthiest to be all
> Had in remembrance alway with delight."—MILTON.

"The fear of the Lord is the beginning of knowledge" (Prov. i. 7), and it is only the fool who despises "the wisdom from above, which is first pure, then peaceable, gentle, and easy to be entreated, full of mercy and good fruits, without partiality and without hypocrisy" (Jas. iii. 17).

The wise man tells us to get understanding (Prov. iv. 7); and where is that understanding to be got? Only in the Word of Truth, which is the foundation of all knowledge, being "able to make us wise unto salvation." Then, indeed, we shall see the littleness of all earthly learning when compared with heavenly wisdom; and, while we contemplate the height and the depth of the knowledge still to be acquired, we shall perceive the comparative insignificance of all mere human efforts, and will be led to cultivate that humbleness of mind which ought ever to characterise the true man of science. How delightful is it to contemplate God in all His works, and to know that all proclaim Him as a God not merely of almighty power, but of wondrous love. This happiness can only be enjoyed when we are led by the Spirit to view all in Christ. The language of Revelation is, that Christ made the world (John i. 10; Eph. iii. 9), and that by Him all things subsist. This is not the mode in which human learning speaks to us. "The world by wisdom knew not God" (1 Cor. i. 21). What a different aspect does creation wear to a Christian from that which it presents to one who is without God in the world! He perceives in all the hand of a Father who is leading Him by green pastures and still waters to His heavenly kingdom. He feels that all things are His in Christ, by the fullest and clearest title. As the Spirit of God at the first brooded on the face of the deep, and brought light and beauty on what was dark and void, so by His gracious influence He enables the believer to view all creation with the enlightened eye of faith, and to see in it an order, a beauty, and an adaptation, such as cannot be appreciated by the mere worldling. He uses the world as not abusing it, knowing that the fashion thereof passeth away (1 Cor. vii. 31).

> " When round Thy wondrous works below
> My searching rapturous glance I throw,
> Tracing out wisdom, power, and love,
> In earth or sky, in stream or grove;
> Let not my heart within me burn,
> Except in all I Thee discern."—KEBLE.

It has been truly remarked by a recent author—"The relations between God and man must be changed before things will be seen clearly. As when our forefathers used to contemplate the solar system from a geocentric point of view (making the earth the centre round which the sun and the universe revolved), all appeared confusion, and every effort to unravel the mystery, by means of 'cycle on epicycle, orb on orb,' only made the entanglement more hopeless; and this could not but last until a bold theorist assumed, in thought, a heliocentric position, and saw (according to reality) all the solar system revolving beautifully around the centre, which the Creator

Himself had established. Thus, whilst man is still a rebel against God, self is his centre, and he cannot constrain the dealings of God to move in harmony with this his plan; nor will he ever see his way out of confusion and embarrassment until he accepts the great truth, 'One is good—that is God.' God is thus the real centre, and all things must subserve His glory. Man must cast aside the weapons of his rebellion and submit to the authority of God ere he can find out the Almighty to perfection. Then will be attained that true soul-abasing knowledge which is characteristic of Divine teaching, and which led the patriarch Job to exclaim—'I have heard of Thee by the hearing of the ear; but now mine eye seeth Thee; wherefore I abhor myself, and repent in dust and ashes.' Thus by the gift of God, and not by his own acquisition, did he attain that wisdom of which he so eloquently had spoken in chapter xxviii., as being so precious and yet so rare, as high as heaven in its source, and yet so practical in its result. 'God understandeth the way thereof, and He knoweth the place thereof: for He looketh to the ends of the earth, and seeth under the whole heaven; to make the weight for the winds; and He weigheth the waters by measure; when He made a decree for the rain, and a way for the lightning of the thunder: then did He see it, and declare [number] it: He prepared it, yea, and searched it out. And unto man He said, Behold, the fear of the Lord, that is wisdom; and to depart from evil is understanding.' Heaven-taught knowledge results in practical holiness."

There is much need that those who are prosecuting science should be warned against the deceivableness of unrighteousness, so that their minds may not at the commencement of their career imbibe that poison, which, when incorporated with their early studies, works insidiously so as to pervade their whole modes of thinking. False views adopted at such a period of life are with difficulty eradicated, and hence the awful responsibility of those who are the means of thus perverting the minds of heedless youth, and of laying a foundation of unsound philosophy. It is satisfactory to think that, in the present day, there are many who feel called upon to lift up their voice against the perversions of science, and to lead the minds of young men to pursue knowledge in a Bible spirit,—with all their getting, to get understanding, even that wisdom which is from above,—and to exhort them that, while not slothful in business, they should ever be fervent in spirit, serving the Lord (Rom. xii. 11).

Our Saviour often spiritualised natural objects when He conversed with man in His bodily presence. "Thus," says Austen, "when the Pharisees spoke of washing their hands before meat, Christ instructs them about spiritual defilement (Matt. xv. 20); when the woman of Samaria came to draw water, He told her of living water (John iv. 10); when disciples brought to Him meat, He tells them that He had meat to eat which they knew not of,—that it was His meat and drink to do the will of His Father (John iv. 34); when the man spoke of his inheritance divided (Luke xii. 13), Christ instructs him and others to beware of covetousness and worldly cares; when the multitudes followed Him after having eaten of the loaves, He counsels them to labour for the meat which does not perish, even for the bread of life (John vi. 26)." The works of God supply many illustrations calculated to aid the Christian in his search after truth. Our blessed Lord in His teaching makes use of the objects around Him in the delivery of the Gospel message, and employs the phenomena furnished by plants as the humble instruments of exhibiting to the minds of His hearers the precious doctrines of His Word. Thus it is that He sanctified such means of instruction; and we fail to ascertain the true mind of the Spirit in such passages, if we do not fully understand the meaning of the illustration. Thomas Taylor, in 1634, says, "Our Saviour borroweth His comparisons from easy and familiar things, such as the sower, the seed, the ground, the growth, the withering, the answering or failing of the sower's expectation; all of these things well known, and by all these would teach us some spiritual instruction. For there is no earthly thing which is not fitted to put us in mind of some heavenly. Christ cannot look upon the sun, the wind, the fire, water, a hen, a little grain of mustard seed, nor upon ordinary occasions, as the penny given for the day's work, the wedding-garment, and ceremonies of the Jews about it, nor the waiting of servants at their master's table, or children asking bread and fish at their father's table, but He applies all to some special use of edification in grace. Earthly things must remind us of heavenly; we must translate the book of nature into the book of grace." Cheever remarks, "that it is frequently necessary to resort to existing realities in order to explain texts of Scripture otherwise inexplicable, and which to the infidel vulgar, to men of the kin of Voltaire and Tom Paine, serve only for ignorant and senseless ridicule." We ought ever to remember, that, "all Scripture is given by inspiration of God, and is profitable for doctrine, for reproof, for correction, for instruction in righteousness" (2 Tim. iii. 16). There is no part of it unimportant. It is a rich mine which cannot be too deeply worked. All our knowledge may be made to bear upon it in such a way as to bring out more of the pure gold. The weeds which strew our path, and the trees and flowers which adorn our gardens and fields, may, in the hands of an enlightened Christian, lead to a clearer view of many statements contained in God's Word.

In the Bible, there is continual reference to the imagery supplied by the material world. The words of Scripture appeal not only to the understanding, but also to the sentiments and affections. They call attention to the beauty of the world around, and they make all subservient to the great end of promoting the glory of God and man's eternal interests. It is said, that "besides the various references made in the pages of Holy Writ, to natural objects in general, there are more than 300 places in which plants are mentioned. Sometimes they occur in Scripture narratives, and tell us of ancient usages; often they remind us of the character, soil, and climate of the scenes of some of the most solemn events of history; in some cases they serve to identify the spots on which they once flourished, as those on which they flourish still; but more often they are emblematic, and are types of persons or of events, or serve as figures by which the feelings of the reader shall be raised from things seen to those which are unseen. But they were never intended to be regarded merely as ornaments of poetry. They had all their lessons, from the Lily of the Valley and the Rose of Sharon, which foreshadowed a coming Lord, down to the Thorn and Thistle, which tell us even yet of man's sin and sorrow."

Dr James Hamilton has well remarked, "Religion and Science long stood in doubtful opposition. There was much needless dread among the believers in the one, and much needless boasting from the disciples of the other. Religious men expressed their conviction with the mingled caution and asperity of fear, while scientific men hastened with an air of unholy triumph to place their discoveries in direct opposition to the statements of Scripture. Time has done much to reverse these positions. The progress of investigation, the growth of scholarship, the enlargement of knowledge, have removed many of the objections formerly brought against Scripture, or enabled its defenders to give them full and satisfactory answers. Now there is less of unbelieving dread on the one hand, less of unseemly boasting on the other. It is no longer necessary to scoff at Revelation in order to appear witty, or required to question its truth in order to appear learned. The advocates of a heaven-given Bible have learned to use the weapons of their opponents; they can walk abroad among the mysteries of science with as fearless a step as the most daring unbeliever, and are able to claim the results of its highest teaching in proof of the statements and doctrines of the Word of God. The attempts to produce opposition between the works and Word of God have utterly failed. The longer it continued the greater became their agreement; as they approached, their enmity was laid aside—they discovered they were friends. The clear eye of science looked on the serene face of religion, and received somewhat of her benignant expression; the pale brow of the ambitious student has bent over the page of revelation, and his eye blazed with light brighter than the fire of genius, for it was radiant with the hopes of a coming immortality; the mightiest of modern sages have laid their honours at the feet of Jesus, and taxed their powers to do Him service. The mysterious music of the starry host has found fitting utterance in strains of glowing eloquence, and the dark history of chaos, written by the Almighty hand on the rocky skeleton of our globe, is telling now to earth's inhabitants of the stupendous power that framed their rolling home—of that unfathomed wisdom, that unbounded goodness, at whose manifestation the morning stars sung together, and at the fuller exhibition of which the redeemed bands chant forth their meed of praise, 'Great and marvellous are Thy works, Lord God Almighty, in wisdom hast Thou made them all.'

"Science has done her part in clearing away objections that might seem to oppose strange statements of Scripture. True science always has done her duty, and ever will continue to do so. But, while thus useful in her circle, there is a knowledge that she cannot teach,—a region of inquiry into which she cannot enter,—'there is a path which no fowl knoweth, and which the vulture's eye hath not seen.' There is a region of meditation too profound for human musing,—a sphere of thought too high for the loftiest aspirings of created intellect. Man may prove much of what has been told him regarding his present condition; but who shall reveal his future? who shall draw aside the veil that shrouds the unseen? The physiologist may prove that at first there was only one man; the philologist may make us sure of the existence of a universal language; the scientific chemist may demonstrate that our first ancestor was made of the dust below our feet; but who shall tell the story of man's thinking, feeling soul? It is here that Revelation speaks out in tones of sweet unquestionable majesty. 'The Lord God formed man of the dust of the ground, and breathed into his nostrils the breath of life; and man became a living soul.' 'The first man is of the earth, earthy; the second man is the Lord from heaven. The first man Adam was made a living soul; the last Adam was made a quickening spirit.' 'Except a man be born again, he cannot enter the kingdom of God.' 'For God so loved the world, that He gave His only-begotten Son, that whosoever believeth in Him should not perish, but have everlasting life.'"

Quatrefages, when tracing the touch of that all-wise and all-powerful hand, which has everywhere diffused life over the surface of our globe and regulated its development, says, "We see nothing extraordinary in the cry of adoration which escapes from Linnæus at the very introduction of his immortal 'Systema Naturæ;' while we can as easily comprehend the feeling which actuated Geoffroy St Hilaire, an illustrious naturalist, when he began and ended one of his last works with the exclamation, 'Glory be to God.'"

God's object in creation is the manifestation of Himself; but while the contemplation of God's works calls forth our wonder and admiration, it should lead us to higher views of the Divine economy in bringing before us that new earth wherein righteousness is to dwell. "It is in the soil of this small planet," Bonar remarks, "that He is sowing His seed, and raising, as in a nursery, those plants which are yet to clothe a glad universe with their everlasting verdure. It is out of the mountains of this planet that He is hewing the stones with which He is yet to build for Himself a temple in every star of the firmament. It is here that He is constructing the materials, and sketching the design, for His palace. It is here that He is weaving and adorning His robes of royal state with the materials furnished by this orb.

It is of the gold of this earth that He is fashioning a sceptre for the hand, and a crown for the head, of Him who is to be Sovereign of the universe. It is from among the lowly dwellers of this narrow region that He is choosing for that King a Bride to share His glory and His love; nay, it is out of this very earth that this King Himself is to arise, or rather, we should say, has arisen; for He who is to have dominion here as King of kings and Lord of lords is an inhabitant of this planet, the native of a Judean village,—Jesus of Nazareth, the woman's seed!"

CHAPTER I.

GENERAL REMARKS ON THE SCIENCE OF BOTANY, AND ON THE VEGETATION OF THE GLOBE.

UNDER the name of natural science are included a description of the objects presented to us in the material world, a systematic arrangement and classification of them, a consideration of the various forms which they assume, of the functions which they perform, of the changes which they undergo, and of the mutual relations which they bear to each other. Studied by some for amusement or the love of knowledge, and by others for professional purposes, it has become an important part of education, and no arguments are required to prove the advantages to be derived from it. By directing the attention to various external objects, it acts most beneficially on the observant faculties, and calls the perceptive powers into vigorous action. It teaches the student to mark the differences and resemblances of objects, and promotes the formation of orderly and systematic habits. It benefits the mind, too, by investing familiar objects with new and increasing interest; and thus the naturalist finds active, healthy, and cheerful occupation for every moment.

"Whoever," says Roscoe, "has turned his mind so as to comprehend the extensive system of the vegetable kingdom, in the manner as at present taught, and has traced this system through its various connections and relations, either descending from generals to particulars, or ascending by a gradual progress from individuals to classes, till it embraces the whole vegetable world, will, by the mere exercise of the faculties employed for this purpose, acquire a habit of arrangement, a perception of order and distinction, and subordination, which it is not perhaps in the nature of any other study so effectually to bestow. In this view, the examination of the vegetable kingdom seems peculiarly proper for youth, to whose unperverted minds the study of natural objects is always an interesting occupation, and who will not only find in this employment an innocent and a healthful amusement, but will familiarise themselves to that regulated train of ideas, that perception of relation between part and the whole, which is of use, not only in the pursuit of this delightful study, but in all the concerns of life. Besides the acquisition of order and arrangement, the bodily senses are highly improved by that accuracy and observation which are necessary to discriminate the various objects that pass in review before them."

The true student of natural history does not confine his attention to mere isolated portions of creation; he studies the harmony of all parts of it, and thus acquires comprehensive views of the unity of the works of God, and of the beautiful adjustments which exist in creation as a whole.

> "Happy is he who lives to understand
> Not human nature only, but explores
> All natures,—to the end, that he may find
> The law that governs each; . . .
> . . . That does assign
> To every class its station and its office
> Thro' all the mighty commonwealth of things,
> Up from the creeping plant to sovereign man."

The objects with which we are surrounded in the material world range themselves under two very distinct heads—the *Inanimate* or

Unorganised, and the *Animate* or *Organised.* The study of the former, or of inert matter, is peculiarly the province of Chemistry and Mineralogy, while the consideration of the latter, or of living bodies, belongs to the *Biological* sciences, as they are termed, of Botany and Zoology. Geology, in place of being denominated a separate science, may be considered as the means by which the sciences of Zoology, Botany, and Mineralogy are grouped together in one harmonious system.

Every one must have recognised in the world around him many evident distinctions between living beings and inanimate objects. Perhaps the most apparent and positive of these distinctions, Dr Carpenter remarks, "is based rather upon a comparison of their mode of existence, than upon an examination of their intimate structure. The ceaseless tendency to *change*, manifested in the life of the former, stands in obvious contrast with the unaltering stability of the latter. The snow-capped mountain rears its summit to the clouds comparatively unaffected by the lapse of ages which have rolled by since its first elevation. But what, compared with *its* permanence, is the duration of any structure subject to the conditions of vitality? To be born—to arrive at maturity

—to die and to decay—is the sum of the history of every being that lives, from man in the pomp of royalty and the pride of philosophy, to the gay and the thoughtless insect that glitters for a few hours in the sunbeam, and is seen no more; from the stately oak, the monarch of the forest through successive centuries, to the humble fungus which shoots forth and withers in a day. How simply, yet how expressively, are these changes described in the words of the sacred writer: 'Our life is as a vapour, which appeareth for a little time and then vanisheth away.'"*

Unorganised bodies consist of separate particles or molecules, united together in definite proportions by the force of affinity, and governed by physical and chemical laws. They are either arranged in shapeless homogeneous masses, forming what are called simple minerals, or they assume certain definite and regular geometric figures, and present themselves to us in the form of crystals. Any increase made to these bodies takes place by additions externally. In a solid state they constitute the crust of the earth, when liquid they form the ocean, and when gaseous, the atmosphere of our globe.

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* Preface to Carpenter's Principles of Comparative Physiology.

Organised bodies, on the other hand, while they likewise are composed of elementary atoms, are distinguished from inorganic matter by not being homogeneous in structure, and by the mode of their increase, which takes place by the assimilation of certain particles received into cavities, and elaborated by a peculiar process into specific compounds, adapted for the nutriment and development of the individual.

Botany has reference to the latter class of bodies, and embraces that division of *organised* nature to which the comprehensive appellation of "The Vegetable Kingdom" has been given. The merits of this science have too often been depreciated by those who ignorantly look upon it as consisting only in the application of learned names to the vegetable productions of the globe. The naming of plants is merely means to an end, and is far from being the true aim of botany. No one can assume an elevated position in botanical science who is not conversant with the structure and physiology of plants, as well as with their external forms and aspects. The time when the acquirements of a naturalist were measured by the number of species he had collected, is now gone by; and names and classifications are looked upon by the man of enlightened views as but the mechanism by which the true principles of science are to be worked out.

Botany, then, aspires to something higher, and more worthy of attention, than the mere naming of plants. Regarding them as organised beings, and as occupying an important place in the scale of creation, it examines the anatomical structure of their various organs, the functions which they perform, the relations which they bear to other objects, whether animate or inanimate, the purposes to which they are subservient in the economy of nature, and the uses to which they are applied. In accomplishing these ends, it takes an enlarged and comprehensive view of the vegetation with which the earth is clothed, and embraces a consideration of the varied aspects under which plants appear in the different quarters of the world.

To see the extent of the science, let us very briefly contrast a few of the vegetable forms with which the earth is clothed. As regards land plants, we have at one extremity of the scale the lichens, such as the small Lecidea * which forms the green spots on alpine sum-

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* *Lecidea geographica*, with its map-like patterns, descends to the level of the sea in lat. 52° N. and lat. 50° S., but in lower latitudes it is seen only on the mountains. On the Himalayas it flourishes at 10,000 feet, and ascends them to 18,000 feet.

mits; or the Gyrophora of the arctic rocks, called *tripe de roche*, on which Franklin and his daring companions subsisted for many weeks; or the Parmelia of cold regions, as represented in fig. 1, with its rounded spots of fructification, containing minute germs, which are blown about by the winds like thin smoke, and which require the aid of the microscope to see them distinctly. At the other extremity we have the majestic Palms of the tropics, as represented by the Coco-nut in fig. 2, *a*, with its lofty unbranched stem, upwards of 100 feet high, having a crown of leaves at its summit, and a large cluster of fruit, which supplies an important article of food to the inhabitants of warm regions; and the mammoth Pine of America, between 300 and 400 feet high. In the case of aquatic plants, we pass from the minute duckweed (*Lemna minor*), the green mantle of our pools (fig. 3), with its leaves less than a quarter of an inch in dia-

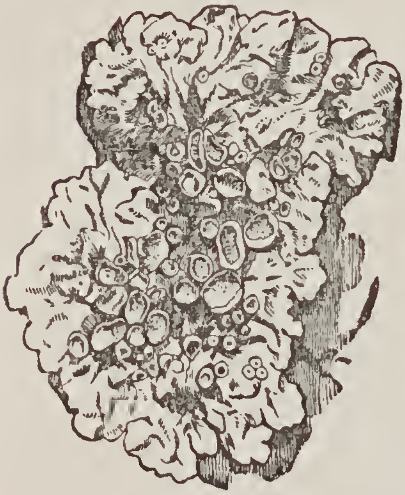
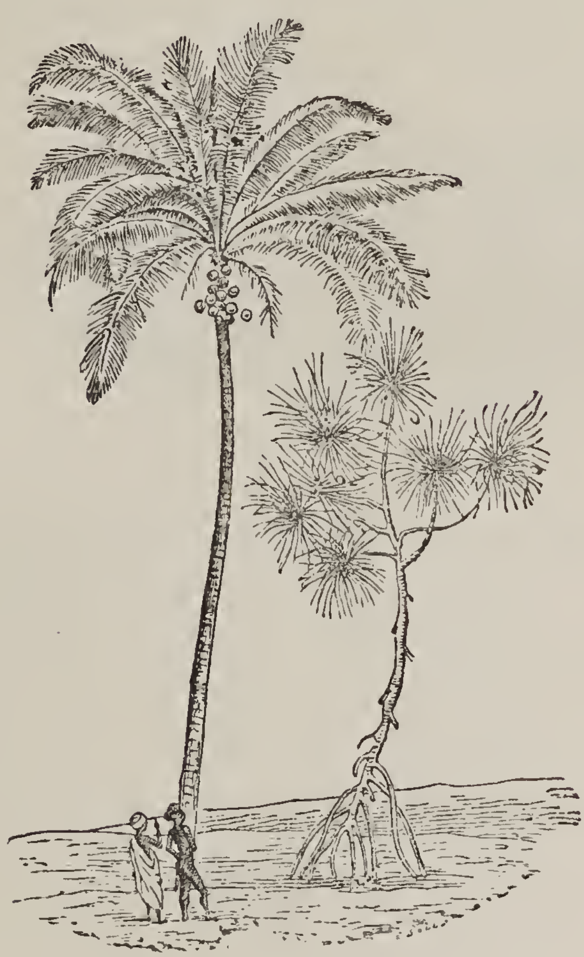


Fig. 1.

Fig. 1.—Lichen (*Parmelia*) with rounded spots of fructification, containing minute germs.

meter, its flowers scarcely visible, and its delicate roots hanging in the water, with their



a Fig. 2. *b*

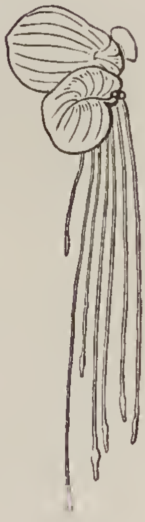


Fig. 3.

Fig. 2, *a.*—Coco-nut Palm (*Cocos nucifera*), with its unbranched stem, crown of leaves, and cluster of fruit. It grows well near the sea, and furnishes food and clothing to the inhabitants of coral islands.

Fig. 2, *b.*—Screw Pine (*Pandanus odoratissimus*), with branched stem, cluster of narrow leaves arranged like a corkscrew, and numerous props in the form of aerial roots which support the stem. Found on coral islands and in warm regions.

Fig 3.—Duckweed (*Lemna minor*), a minute plant forming a green covering of pools. The minute flowers arise from the floating leaves, and the roots are entirely in the water, their extremities being provided with a little sheath, which is a beautiful microscopic object.

beautiful sheathed points, to the enormous *Victoria regia* of the South American waters (fig. 4), having its leaves six feet in diameter and its showy flowers one foot across. If we take parasites, or plants living upon others, we have a remarkable contrast between the minute mould (*Penicillium*), (fig. 5), with its cellular spawn or root-like processes *a*, its slender stalk *b*, and its microscopic bead-like germs *c*, and the gigantic Rafflesia of Java (fig.

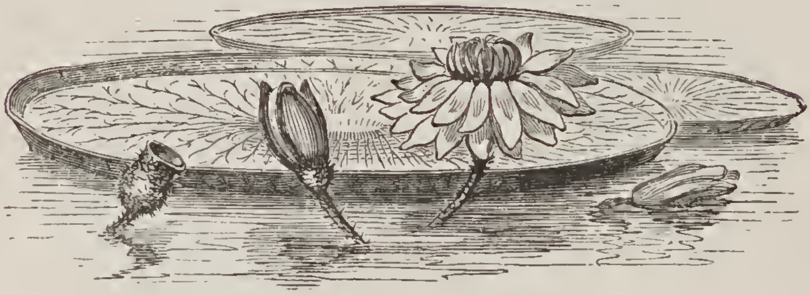


Fig. 4.

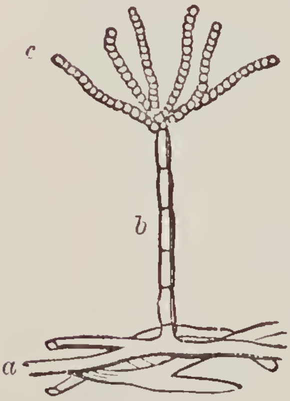


Fig. 5.

Fig. 4.—*Victoria regia*, the largest known water-lily, found in lagoons in South America. Its leaves 4-6½ feet in diameter, and flowers 1 foot across. The plant has flowered in warm tanks in several hot-houses in Britain, as at Chatsworth, Sion House, Kew, Veitch's Nursery, Exeter. An interesting account of this plant, and of our native water-lilies, has been published by Dr George Lawson.

Fig. 5.—A minute parasitic fungus constituting a kind of mould (*Penicillium*). There are root-like processes below which form the spawn or matrix *a* whence the plant arises. By means of these it feeds on vegetable substances. Its stalk *b* is composed of cells or little bladders placed end to end, and at the summit are numerous bead-like bands *c*, consisting of minute microscopic germs. The spawn of this mould, branching and interlacing in a peculiar way, so as to form a

6), composed of a conspicuous brown-coloured

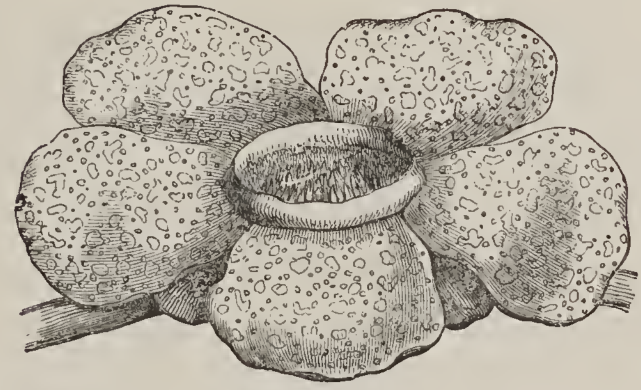


Fig. 6.

flower, three feet in diameter, and capable of holding twelve pints of fluid in its cup.

Widely separated though these plants may be in their physical characters, they are all mutually subservient to each other. Every member of the vegetable kingdom, from the most lofty to the most minute and transient—from the cedar on Lebanon to the hyssop or caper plant * on the wall—has its peculiar

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rounded leathery-like mass, is said to be the plant which has recently been noticed as giving rise to the acetous fermentation, and producing vinegar when put into syrup. In this condition, it separates in a remarkable manner into two portions after a period of six weeks or two months, each forming an independent mass capable of going through the same process of division. It has been called the vinegar plant.

Fig. 6.—*Rafflesia Arnoldi,* a gigantic parasite found in Java and Sumatra. The plant consists entirely of a flower, with roots by which it attaches itself to other plants. The flower is of a peculiar brown colour, and is three feet in diameter.

* In speaking of the ruins of Petra, Mr Porter says, "The products of nature are alone perennial; for while the monuments of man are all spoiled, the delicate branches of the caper plant [Hyssop] hang down as fresh and beautiful from the chinks in the rock as they did two

office, and is fitted to effect an especial end in the economy of nature.

> "Each moss, each shell, each insect, holds a place,
> Important in the plan of Him who framed
> The scale of beings ; holds a place, which, lost,
> Would break the chain, and leave a gap behind
> Which nature's self would rue."—STILLINGFLEET.

Minute plants are not to be despised either as regards their structure or their use in the economy of the world. The structure of a small moss displays exquisite symmetry and beauty. The markings on the insignificant diatoms are truly wonderful, and can only be seen under the highest powers of the microscope. Lichens and mosses,—plants so minute as to be overlooked by the ordinary observer,—are the means employed by the Creator to prepare a soil in which the seeds of the higher plants can vegetate. Sometimes, as Humboldt remarks in his "Aspects of Nature," volcanic forces suddenly elevate above the surface of the boiling waves a rock covered with scoriæ; sometimes by a long-continued and more tranquil series of phenomena, the collective labours of united zoophytes raise their cellular dwell-

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thousand years ago, and the foliage of the wild fig and tamarisk is as rich, and the flower of the oleander as gaudy, as they were when the princes of Edom dwelt in the clefts of the rocks, and held in pride the height of the hills." — Jer. xlix. 16. — Murray's Handbook for Travellers in Syria and Palestine, by the Rev. J. L. Porter.

ings on the crests of submarine mountains, until, after thousands of years, the structure reaches the level of the ocean, when the creatures which have formed it die, leaving a low, flat coral island (fig. 7). No sooner is the rock of the newly raised island in direct contact with the atmosphere, than there is formed on its surface a soft, silky net-work of lichens, appearing to the naked eye as coloured spots and patches.

When the lava poured forth by a volcano is cooled, it is speedily occupied by patches of lichens (fig. 1, p. 8). The reproductive, although invisible, germs of these plants are produced in vast abundance, and are constantly floating in the atmosphere, ready to alight on any object that may come in their way. Many of them have the power of adhering to rocks, and of causing their disintegration. Some of them secrete an acid (chiefly oxalic), by means of which they corrode the rock, and become inseparable from it. From the materials of the rocks, aided by the atmosphere and moisture, they are able to derive all the requisites for their growth and nourishment. In this way they prepare a slight stratum of vegetable mould, and by their decay form a soil in which mosses and ferns can grow. These, in their turn decaying, make way for grasses and rock-plants, and by successive changes a soil is produced in which the seeds of trees can vegetate, when carried thither by the agency of winds or other causes.

To such minute agents do we trace the soil formed on the coral islands of the Pacific Ocean, which ultimately affords nourishment to the Coco-nut Palm (fig. 2, *a*, p. 9). This palm, all parts of which are put to some use, grows luxuriantly on coral-made islands after their emergence from the ocean. It furnishes to the natives food, drink, clothing, materials for building, utensils of all kinds, mats, cordage, fishing-lines, and oil. The Pandanus or Screw Pine (fig. 2, *b*, p. 9) is another early inhabitant of coral islands, where it flourishes luxuriantly. As its branches spread, it sends out prop after prop to support the trunk, and to fix the tree in the ground. Its large mass of fruit affords a sweetish article of food, which can be kept for some time. By means of these fruits, and by fishing, populations of 10,000 persons are supported, according to Dana, on the single island of Taputeouea, whose whole habitable area does not exceed six square miles.

In nothing is God's infinity and man's littleness more strikingly exhibited and contrasted, than in the operations of nature upon a grand scale; and this is particularly evident in the instance of the formation of the coral islands, and their vegetable productions. The extreme simplicity of the means employed for the attainment of such vast ends, cannot but be a subject of astonishment and admiration to every reflecting mind; and this simplicity is apparent in all the ways and workings of God. In fig. 7 is represented one of these coral islands in the Pacific Ocean, the centre occupied by a lake, and the circumference formed by a madreporic reef, on which vegetation flourishes.

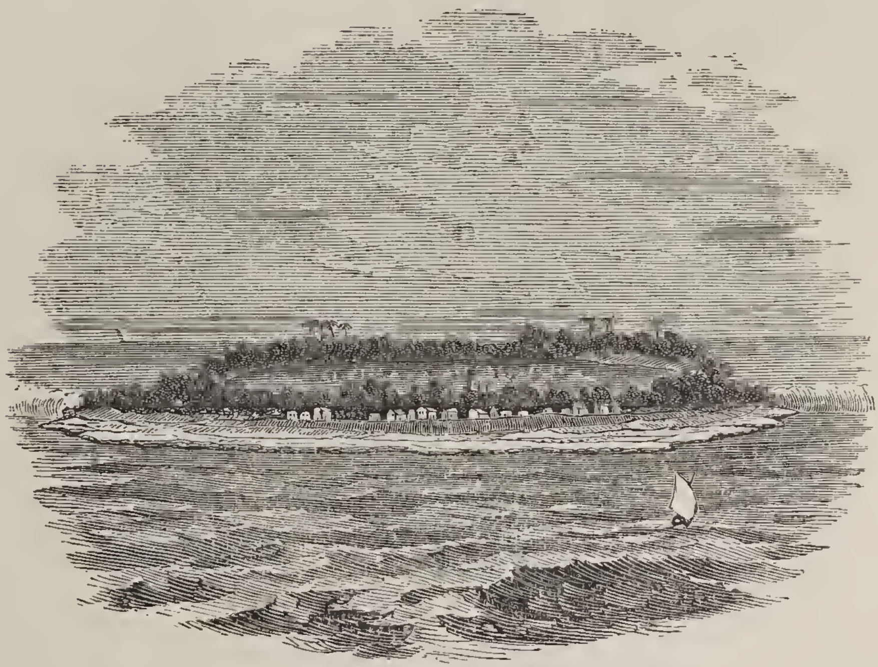

Fig. 7.

Fig. 7.—A madreporic or coral island in the Pacific Ocean, with a lake or lagoon in the centre.

The means by which such islands are constructed are seen in figs. 8, 9, 10, which represent some of the polyps that unite in this work. Each of the specimens consist of an immense number of these minute animals

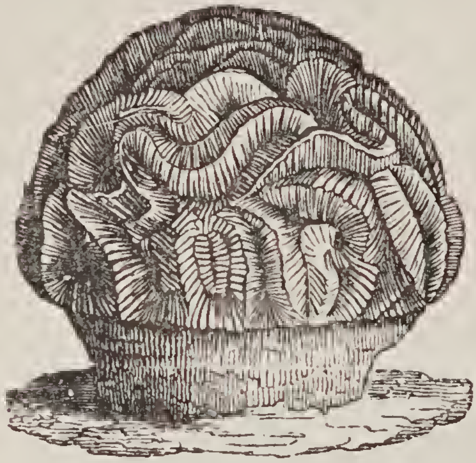

Fig. 8.

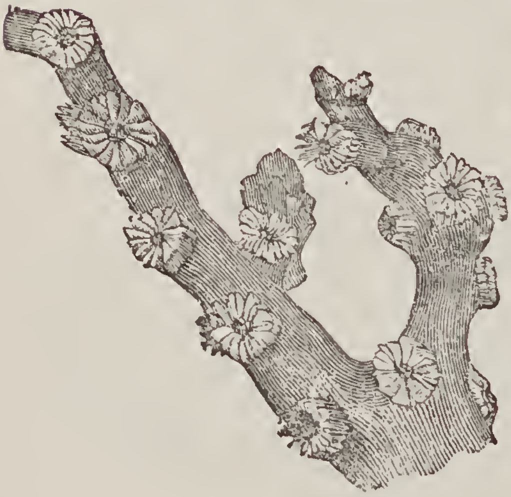

Fig. 9.

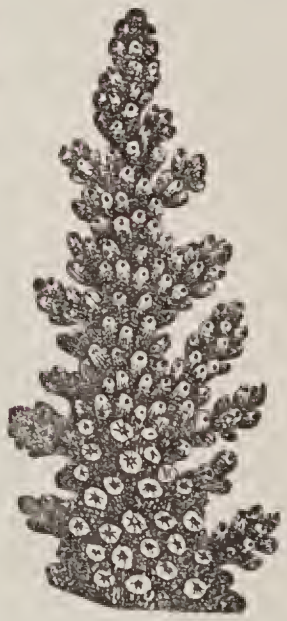

Fig. 10.

Fig. 8.—*Meandrina labyrinthica*, a species of coral polyp. The whole mass consists of numerous polyps combined.

Fig. 9.—*Oculina hirtella*, another set of coral polyps.

Fig. 10.—*Madrepora muricata*, a third set of coral polyps.

united together on a common stalk or base, forming their durable polypodoms or polyp-houses, and thus gradually accumulating large masses of hard materials which resist the action of the waves, and ultimately form solid land. Gosse says, "When I look on the multitudes of polyps inhabiting such a structure, each bearing his starry crown, and all engaged in harmony, building up, wall by wall, and cell by cell, an edifice whose walls are of crystalline clearness, often studded with what look like gems, as in Membranipora and Crisia, and whose cells, as in Cellularia, are closed with pearly doors; when I watch the building growing up into a city, a commonwealth, of myriad individuals; when I know that, besides the separate life of each, there is a common life, a bond of identity, that constitutes the vast assemblage, but one Being—One, though Many—I cannot help thinking of the heavenly city, the Jerusalem which is above" (Rev. xxi.).* How beautifully are the labours of these animals referred to by James Montgomery in the following lines:—

"Millions of millions thus, from age to age,
With simplest skill, and toil unweariable,
No moment and no movement unimproved,

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* Gosse, "Aquarium," p. 126.

Laid line on line, on terrace terrace spread,
To swell the heightening, brightening, gradual mound,
By marvellous structure climbing tow'rds the day.
Each wrought alone, yet all together wrought,
Unconscious, not unworthy instruments,
By which a Hand invisible was rearing
A new creation in the secret deep.
Omnipotence wrought in them, with them, by them ;
Hence what Omnipotence alone could do,
Worms did. I saw the living pile ascend,
The mausoleum of its architects,
Still dying upwards as their labours clos'd ;
Slime the material, but the slime was turn'd
To adamant by their petrific touch ;
Frail were their frames, ephemeral their lives,
Their masonry imperishable. All
Life's needful functions, food, exertion, rest,
By nice economy of Providence
Were overruled, to carry on the process
Which out of water brought forth solid rock."
—*The Pelican Island*, Canto II.*

When compared with this amazing edifice, raised by the weakest creatures in existence, what are all the works of man ? How different is it with his designs ! How complicated are the means which he employs for the attainment of his projects ! D'Aubigné well remarks :—"When man would raise a shelter against the weather,—a shade from the heat of the sun,—what preparation of materials, what scaffolding and crowds of workmen, what trenches and heaps of rubbish! But when God would do the same, He takes the smallest seed, that a new-born child might clasp in its feeble hand, deposits it in the bosom of the earth; and from that grain, scarcely distinguishable in its commencement, He produces the stately tree, under whose spreading branches the families of man may find a refuge."

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* A full-grown specimen of *Eschara foliacea*, a kind of British coral, has been estimated by Gosse as containing a population of 576,000 inhabitants. Montgomery's description applies to it as well as to the tropical coral.

Let us trace the steps of this process in the case of an ordinary seed. The small germ of life deposited in the earth is acted on by moisture, heat, and air, and thus accomplishes all the wonders of creation. The fluid enters the rootlets, the sap rises through the tubes and cavities by a beautiful law of imbibition and attraction, it reaches the branches and the upper part of the leaves, is exposed to the action of air and light, and then returns by the lower surface of the leaves to the bark, forming in its course various secretions and products which are required for the purposes of vegetable life. A few simple elements in the hand of the Creator are all that are required to work out this great plan.

"Thus He who makes and peoples worlds still works
In secrecy, behind a veil of light;
Yet, through that hiding of His power, such glimpses
Of glory break, as strike presumption blind,
But humble and exalt the humbled soul,

> Whose faith the things invisible discerns,
> And God informing, guiding, ruling all :—
> He speaks, 'tis done ; commands, and it stands fast.
> He calls an island from the deep—it comes ;
> Ordains it culture—soil and seed are there."
> —MONTGOMERY, *Pelican Island.*

The lichens and mosses of the arctic and antarctic regions are slowly preparing a soil for a more highly-organised race. The summit of the mist-crowned mountain, although unproductive of any of those plants which are directly useful to man or animals, is covered with lichens, preparing a soil which is afterwards carried down by the streams to fertilise the plains below. The most despised weeds thus lay the foundation for the growth of the trees of the forest; and in the course of a few years the sterile rock or coral-formed island is converted into a natural and luxuriant garden. By Nature's chemistry, the bare rock becomes buried in crumbling mould, in which from time to time the seeds of plants are deposited. By degrees, the slender blades of grass shoot through the dark brown earth, the green herbage covers the soil, flowers expand their blossoms, and shrubs and trees adorn the landscape,—

> "Seeds, to our eye invisible, can find
> On the rude rock the bed that fits their kind ;

> There in the rugged soil they safely dwell,
> Till showers and snows the subtle atoms swell,
> And spread th' enduring foliage ;—then we trace
> The freckled flower upon the flinty base :
> These all increase, till, in unnoticed years,
> The sterile rock as grey with age appears
> With coats of vegetation thinly spread,
> Coat above coat, the living on the dead ;
> These then dissolve to dust, and make a way
> For bolder foliage nursed by their decay."
> —CRABBE, *The Borough.*

As with God's works of creation and providence, so it is with His work of grace. By imperceptible means He accomplishes His mighty plans. The dawning of light in the mind of man is often unseen at first, but it gradually brightens into the perfect day. The little leaven leavens the whole lump. The small mustard-seed becomes the tree.* The spark of grace is fanned into a flame, and pervades the entire inner man. From the contemplation, then, of all God's works, let us learn not to despise the day of small things. God often chooses those who are despised by the world to work out His mighty plans. "The weakness of God is stronger than men." "Not many wise men after the flesh, not many mighty, not many noble, are called: but God hath chosen the foolish things of the world to confound the wise; and God hath chosen the weak things of the world to confound the things which are mighty; and base things of the world, and things which are despised, hath God chosen; yea, and things which are not, to bring to nought things that are: that no flesh should glory in His presence" (1 Cor. i. 25-29). The despised fishermen of Galilee were chosen as His missionaries to proclaim the truth, to advance His kingdom, and to prepare the way for the new earth, wherein righteousness shall dwell. Truly, "His ways are not as our ways, nor His thoughts as our thoughts" (Isa. lv. 8, 9). "How unsearchable are His judgments, and His ways past finding out" (Rom. xi. 33).

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* It may be noticed here that the mustard-plant of Palestine is not a herbaceous plant like that of Britain, but is in reality a tree (*Salvadora persica*), on the branches of which the fowls of the air can lodge.

CHAPTER II.

ON THE STRUCTURE AND DEVELOPMENT OF PLANTS.

A plant consists of certain parts called *organs*, which assume various forms, according to the functions which they perform in the economy of vegetable life. These organs, generally speaking, are denominated, root, stem, leaves, and flowers. The first three are specially concerned in the nourishment of the plant, while the last is connected with the production of fruit and seed, and the continuance of the species. There is a common axis, one part of which descends into the earth, and is connected with the root system, while the other ascends into the air, and bears leaves and flowers. Each of these parts gives origin to buds, which in the former are developed as roots and rootlets, in the latter, as leaves and leaflets of various kinds. The ordinary leaf may be said to be the type of the organs connected with the ascending portion of the axis. This type undergoes various modifications. Some leaves are green, others are coloured,—some are placed close together, others are separated,—some are thick and fleshy, others are thin and membranous, or mere scales,—some are flat, others are folded so as to become hollow,—some are changed into tendrils, others into prickles. The leaflets forming the flowers are usually very different in aspect from the ordinary leaf. It will be found, however, that they are all formed according to the leaf-law, and that they often show this fact unequivocally when altered by cultivation or otherwise.

In fig. 11 will be seen an ideal plant with its different parts. There is a general axis from which proceeds the descending part forming the root *r*, with its fibrils *b b*; the ascending part forming the stem *a*, with its various joints or separate spaces *i i i i*. On the stem, leaves are produced, first in the form of temporary seed-leaves *c*, and then in the form of simple or compound leaves *l l l*. Buds, *d d d d*, are produced at the points where these leaves join the stem. In the progress of time the flower is produced, consisting of calycine leaves or sepals *s*, corolline leaves or petals *p*, staminal leaves or stamens

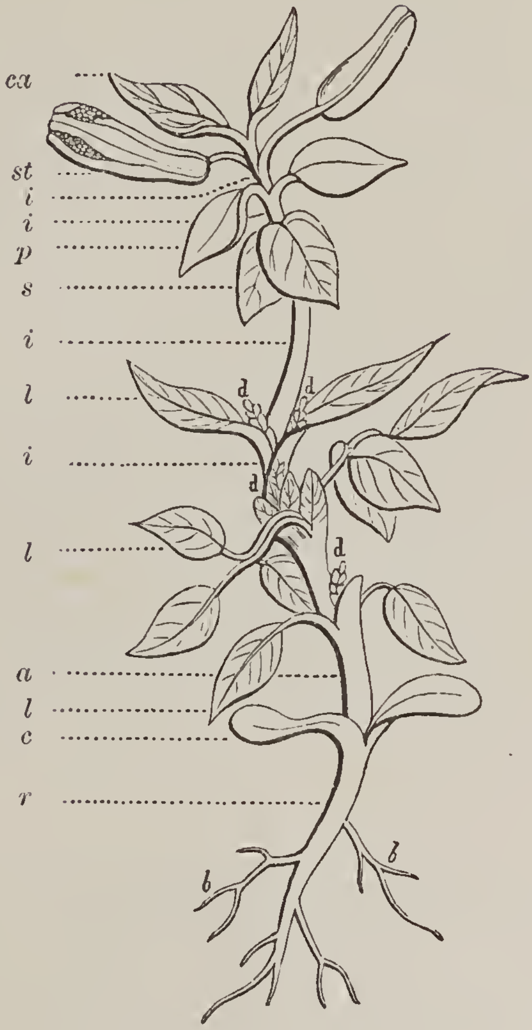

Fig. 11.

Fig. 11.—An ideal representation of a flowering plant chiefly after Schleiden. There is a general axis from which proceeds the descending system, forming the root *r*, with its fibrils *b b*. From the same axis proceeds the ascending system, forming the stem *a*, with its various joints or internodes *i i i i*. On the ascending axis leaves are produced, first in the form of cotyledons or seed-leaves *c*, and then in the form of ordinary leaves *l l l*, in the axil of which buds, *d d d d*, are produced. In the progress of time the flower and organs of reproduction are developed, and these are formed upon the type of the leaf ; the calycine leaves or sepals *s*, the corolline leaves or petals *p*, the staminal leaves or stamens *st*, and the pistilline leaves or carpels *ca*. The ovules or

st, and pistilline leaves or carpels *ca*, which cover the young seeds or ovules. The latter are either attached to the edges of the carpels or are produced at the extremity of the ascending axis. In this ideal figure the parts of the flower or blossom are represented as separated from each other by spaces. In general they are found close to each other in nature.

Such is a comprehensive view of the organs of plants. We shall now proceed to consider them in succession—commencing with their structure, as observed by means of the microscope, and then tracing the young plant from its earliest state, through its different stages of growth and development, up to the perfect fruit and seed.

I.—ON THE MICROSCOPIC STRUCTURE OF PLANTS.

As regards their minute structure, plants have been divided into those which are composed entirely of small bladders or vesicles called *cells* (fig. 12), united together in various ways

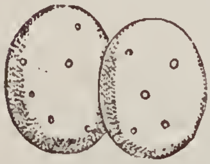

Fig. 12.

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young seeds are either produced on the edges of the carpels or at the extremity of the axis enclosed by the carpels. Both the nutritive and reproductive organs are formed upon a common type.

Fig. 12.—Two cells or vesicles (magnified), which enter into the composition of plants. The dots are places where the membrane, forming the walls of the cells, is thin.

(fig. 13); and those which are furnished not only with cells, but with long closed tubes called *vessels* (fig. 14). The former are denominated *Cellular plants*, and they may be illustrated by mushrooms, moulds (fig. 5, p. 10), sea-weeds and lichens (fig. 1, p. 8), which have no conspicuous flowers, and are produced by small cellular germs; the latter receive the name of *Vascular plants*, and are seen in the case of ordinary trees, shrubs, and herbs which have more or less evident flowers, and are reproduced by seeds.

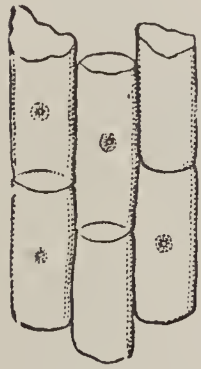
Fig 13.

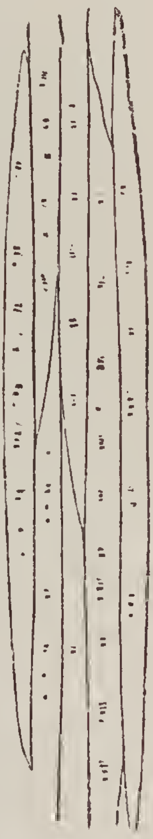
Fig. 14.

The structure of the cells and vessels of plants can only be fully seen by the aid of the microscope, an instrument which we shall immediately describe. The examination of these tissues amply repays the trouble attendant upon it. In some cells and vessels there are seen beautiful markings in the form of dots

Fig. 13.—Cylindrical cells (magnified) united together and forming cellular tissue. Some of them are represented as containing small cellules or nuclei which are employed in the production of new cells.

Fig. 14.—Elongated spindle-shaped woody tubes, closed at each end and united together, so as to form a kind of vascular tissue (magnified).

(figs. 15 and 16), or rings (fig. 17), or bars (fig. 18), or fibres, coiled up like a corkscrew (figs. 19 and 20). Hence arise the various names of dotted, annular or ringed, barred or ladder-like, and spiral cells and vessels. These, along with woody tubes (fig. 14), may be seen in different parts of the same plant.

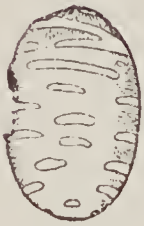
Fig. 15.

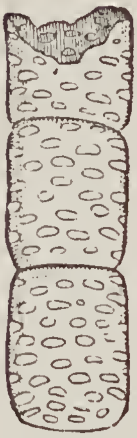
Fig. 16.

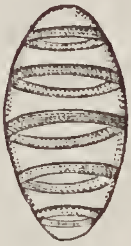
Fig. 17.

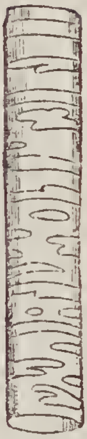
Fig. 18.

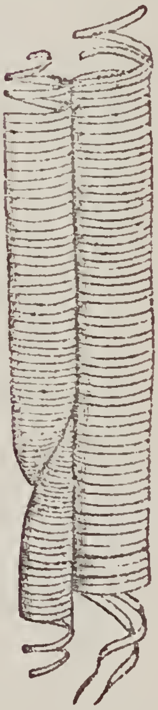
Fig. 20.

Common mould (fig. 5, p. 10) and mushrooms are composed of cells united together; so are the pith of trees, cotton, cork from the outer bark of the cork oak, rice-paper, and the paper of the ancients, made from

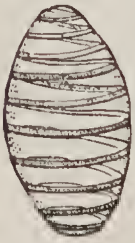
Fig. 19.

Figs. 15 to 20.—Various forms of cells and vessels magnified. 15. Dotted cell. 16. Dotted or pitted vessels composed of united cells with the

the papyrus—the bulrush of Scripture—whose nodding heads of flowers (fig. 21) so well correspond with the statement of the prophet, "Bow down his head as a bulrush." All fleshy fruits, as the peach, and succulent roots, as turnip and carrot, contain a large quantity of cellular tissue; and the object of the horticulturist in many instances is to increase it, and thus to render vegetables tender and succulent, which would otherwise be tough and dry. Cells often become hardened and thickened by matter deposited inside. Thus the hard shell of seeds, and the stone of fruits, consist of woody cells. The coverings of some seeds,

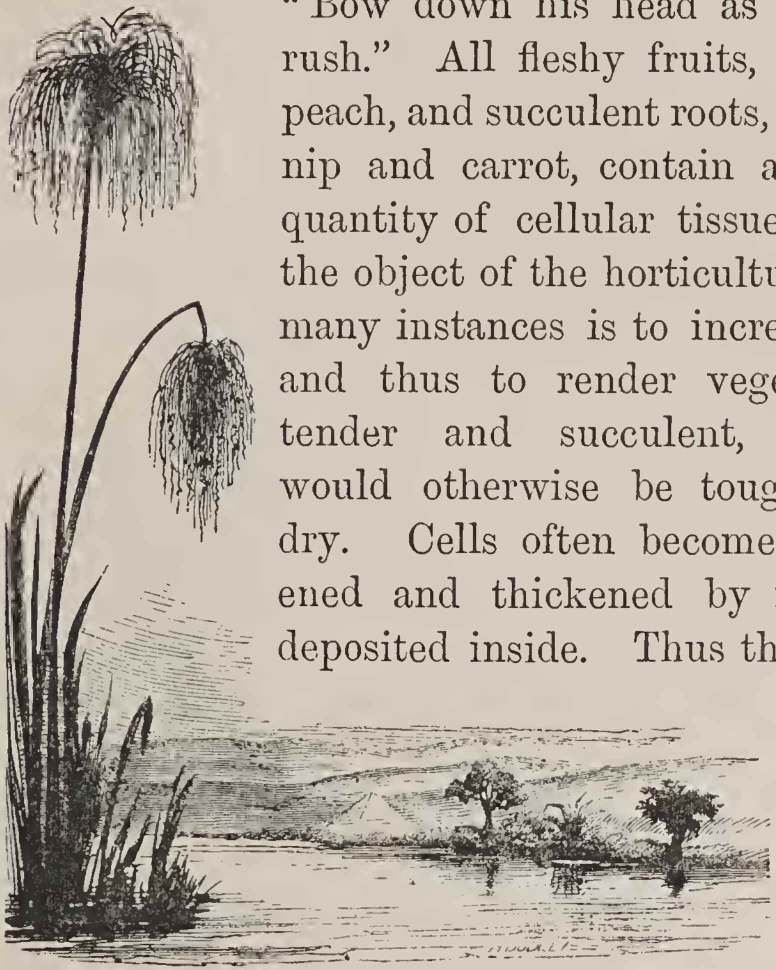

Fig. 21.

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partitions obliterated. 17. Annular or ringed cell, with fibres in the form of rings. 18. Barred vessel, with lines or bars formed by fibres. 19. Spiral cell, with an elastic spiral fibre inside. 20. Spiral vessels, with spiral fibres inside capable of being unrolled.

Fig. 21.—*Papyrus antiquorum*, the bulrush of Scripture. It grows in the Nile, and is used for making light boats (Isa. xviii. 2). The

as *Collomia*, exhibit beautiful spiral cells (fig. 19), the fibres of which, when moistened by water, uncoil in a remarkable manner, and form a beautiful object under the microscope. The use of this seems to be to fix the seeds in the moist soil after being scattered. Peculiar annular cells (fig. 17) are met with in Cactuses.

The woody parts of plants consist of elongated tubes, tapering to each end (fig. 14, p. 27), and rendered tough by woody matter deposited inside. These woody tubes can be separated from the bark and stems of many plants by maceration or steeping in water; and in this way hemp, flax, and bast are procured. In fig. 22 the plant which furnishes New Zealand flax is shown. Each minute thread of this substance con-

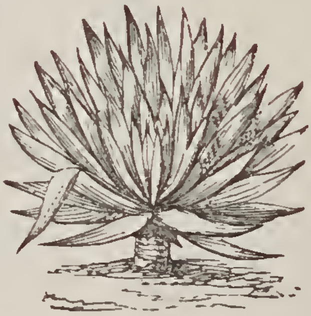

Fig. 22.

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babe Moses was exposed on the Nile in an ark of bulrushes (Exod. ii. 3). In Lucan's Pharsalia, iv. 136, we meet with the following:—"Conseritur bibula Memphitis cymba Papyro." We may hence conclude that the ark in which the infant Moses was laid in the Nile,—an ark of bulrushes, daubed with slime and with pitch,—was a small boat constructed with Papyrus. In Abyssinia, according to Bruce, boats are made of this plant. The same plant is probably referred to by the name of rush in Job viii. 11, and Isa. xxxv. 7, and by the name of paper-reed in Isa. xix. 7. In South America, at the present day, a similar kind of bulrush (*Scirpus lacustris*), is used for making balsas or boats. Weddell crossed the rivers on barks formed of two great boats or cylinders of bulrushes bound together, and with elevated tapering extremities.

Fig. 22.—*Phormium tenax*, the plant (much reduced in size) which yields New Zealand flax, composed of woody vessels.

sists of numerous woody tubes overlying each other, as represented in fig. 14, and thus having considerable tenacity. Pitted or dotted vessels (fig. 16), are the largest kind of tubes in plants. They are well seen in the sugar-cane and in the bamboo. Spiral vessels are met with abundantly in the higher tribes of plants. They may be procured from common asparagus after being boiled, by separating the cellular portion in water under the simple microscope. The spiral fibre of the vessels may be exhibited by making a superficial cut round the leaf-stalk of a geranium or strawberry, and then pulling the parts gently asunder. When the coil is unrolled, it appears like the threads of a cobweb. In the common hyacinth and lilies, these spiral fibres can be easily seen. In the case of the banana (fig. 23), the spiral fibres are so abundant, that they are pulled out and used as tinder in the West Indies. In the stem of trees, the spiral vessels exist around the pith. In the common garden balsam, many varieties of vessels exist which can be readily separated under the microscope. Peculiar vessels, having bars of fibres arranged like the steps of a ladder, occur in ferns (fig. 24), and especially in the stems of tree ferns.

Thus all the parts of plants, including root, stem, leaves, flowers, and fruit, are composed of cells and vessels of different kinds, either separate or combined; and by means of these simple tissues the Creator carries on all the wondrous

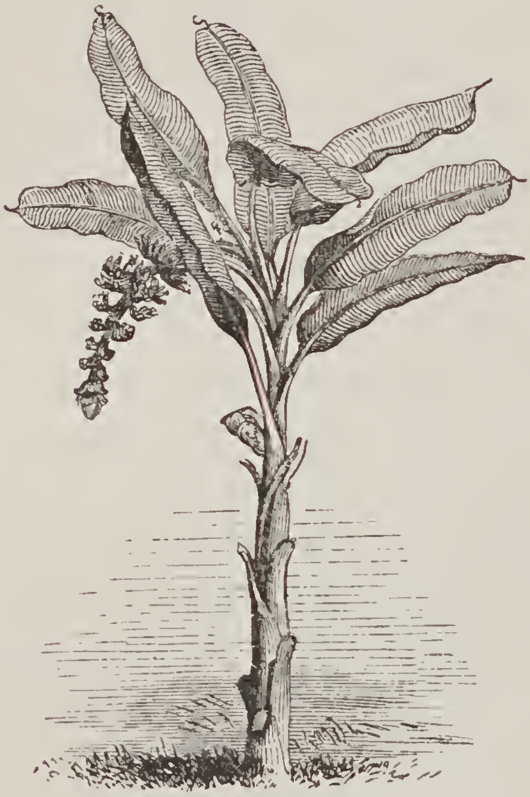
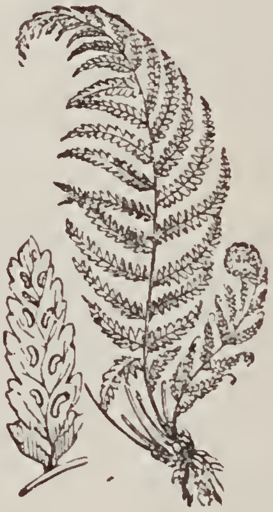


Fig. 23.



b Fig. 24. *a*

Fig. 23.—Aerial stem of Banana (*Musa sapientum*), formed by sheathing leaves. The proper stem is subterranean, and the stem shown in the figure is a shoot sent up, bearing leaves and fruit, and then decaying, to give place to another shoot. The cluster of fruit is seen at the top. The extremity of the cluster is abortive; the flowers at the base of the stalk bear perfect fruit. The plant contains numerous spiral vessels, some of them having flat ribbands composed of numerous fibres combined, coiled up in their interior.

Fig. 24.—*Athyrium Filix-fœmina*, a British fern. *a* Entire plant much reduced in size, with root and frond bearing fructification; *b* Portion of the frond or leaf showing the fructification.

processes of vegetable life. The absorption or imbibition of nourishing fluids takes place by the cells of the root; the sap then rises through the cells and vessels and intercellular canals of the stem; it reaches the cells and vessels of the leaf, and is there exposed to the action of air and light, so as to fit it for the various secretions given off as it descends through the cells and vessels of the bark. Thus the functions of nutrition or nourishment are accomplished. The cells and vessels of the flower, on the other hand, undergo changes, and are united in the form of various organs so as to enable them to perform the functions of reproduction, or the production of seed.

To cells we must trace all the phenomena of vegetable life; they constitute the first tissue of all plants, and to them we must refer all the other tissues. In their unchanged primitive condition cells are seen in cellular plants, and in the pith, the pulp, and the succulent parts of vascular plants; when thickened by hard deposits inside they form the woody cells of the stones of fruits, and when at the same time elongated they appear as woody fibres, giving firmness to the stems and to the ribs of the leaves; and when lengthened out and lined with a spiral thread they appear as spiral vessels of various kinds.

Cells also contain in their interior small nuclei (fig. 13, p. 27), by the action of which new cells are produced; and they have also the power of dividing into two, and thus multiplying. These little bladders, formed and endowed with vitality by the Almighty, are thus made to accomplish the functions required in the economy of plant life.

Besides a general movement of sap, there are also special movements occurring in cells and vessels. In the cells of aquatic plants, such as *Chara* (fig. 25), and *Vallisneria* (fig. 26), there is a distinct and regular motion of granules, which is easily seen under the microscope. These movements are promoted by moderate heat, and they seem to take place in a spiral manner round the cells. They appear to be connected with the life of the individual cell,

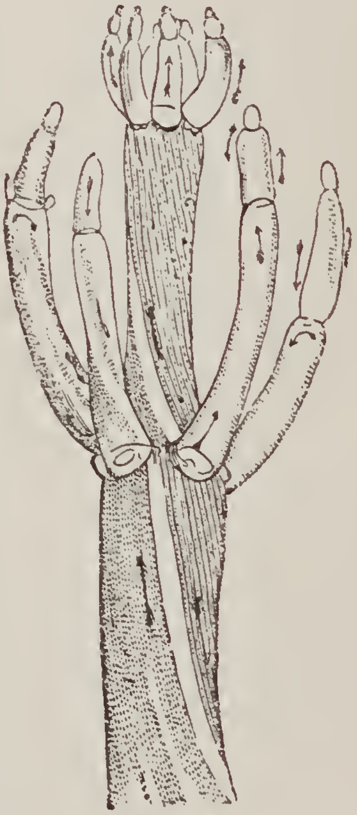


Fig. 25.

Fig. 25.—A small portion of a Chara magnified to show the intracellular circulation. The arrows mark the direction of the fluid and granules in the different cells. The clear spaces are parts where there is no movement. The circulation in each cell is independent of that in the others.

and the formation of new cells. In the jointed hairs seen in the flowers of the Virginian spider-wort, and in the hairs of the common nettle, similar motions are observed. In certain vessels of plants called *laticiferous,* movements of granular matter have been detected. These vessels have a peculiar structure, and unite together freely, as seen in fig. 27, so as to form a sort of net-work. They are best seen in plants with milky or coloured juices, as the India-rubber and Gutta-percha plants, the Cow-tree (fig. 28), Spurges, and Celandine. Some consider the

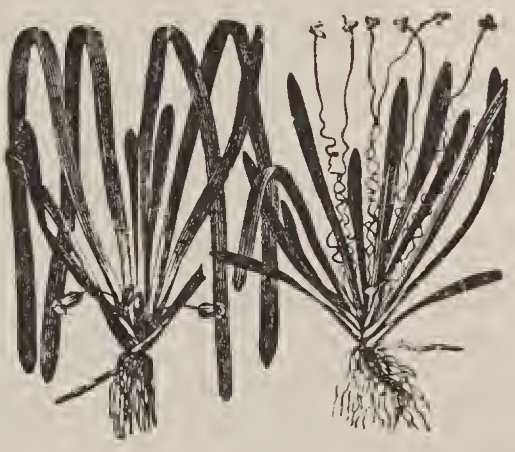


Fig. 26.

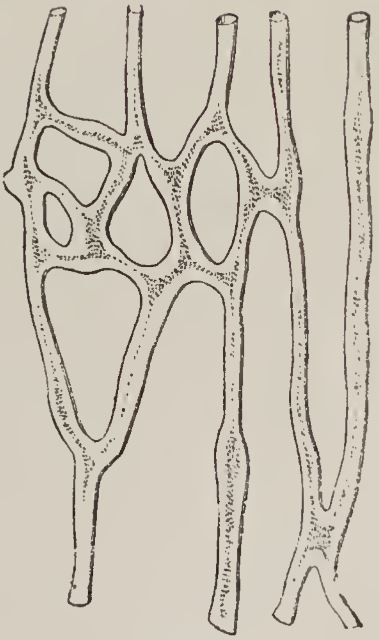


Fig. 27.

Fig. 26.—*Vallisneria spiralis,* an aquatic plant, found in ditches in the south of Europe (reduced in size). In the separate cells movements of fluids take place. *a* Stamen-bearing plant ; *b* Pistil-bearing plant.

Fig. 27.—Laticiferous vessels of the common Dandelion. The vessels unite together freely, and movements of granular matter take place in them.

motions in these vessels as being connected with the return of the sap from the leaves to the bark. As all the textures of which we have been treating are microscopic, it seems right that we should now explain the structure of the microscope itself.

Fig. 28.

II.—DESCRIPTION OF THE MICROSCOPE.

To those who wish to study the minute structure of plants, a *Microscope* is indispensable; and it may not be out of place here to give a short notice of it. The microscope is an instrument which enables us to see objects which are placed at a very short distance from the eye, or to see very minute objects which would otherwise be invisible. In a *simple microscope* we view the object directly through a lens, or a combination of lenses. This instrument, however, does not give a large field of vision, and in using high magnifying powers

Fig. 28.—*Galactodendron utile*, or the Cow-tree of the Caraccas. It yields a white bland fluid, which is used like milk, and is contained in laticiferous vessels, which, when punctured, pour it forth in large quantity.

we approach too near the object. In very minute researches, the *compound microscope* is that which is used. This instrument is constructed on a different principle from the simple microscope. An image of the object to be examined is formed by one lens or set of lenses, and this image is viewed as an original object by the eye of the observer applied to another glass.

The woodcut (fig. 29) representing a compound microscope, as constructed by Smith and Beck of London, with the accompanying diagram, will enable us to explain the nature of the instrument. It is supported on a stand A, which bears a stage-plate *d*, on which the object to be seen is placed between two pieces of glass; a mirror *b*, for throwing light upwards on the object, through a plate *c*, called a diaphragm or stop, perforated with holes of different sizes, with the view of concentrating the light more or less by excluding the outer rays coming from the mirror. The body of the microscope, *h f*, is furnished with lenses at each end; *f* is the object-glass, or that next the object on the stage, and is composed of lenses of different forms, which are rendered complete as regards light, or *achromatic*, by being formed of glass of different densities, such as crown-glass and flint-glass; *h* is the eye-piece, or the lens to which the eye of the

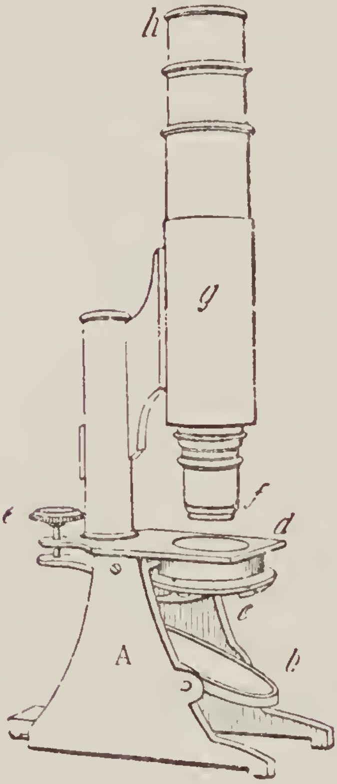


Fig. 29.

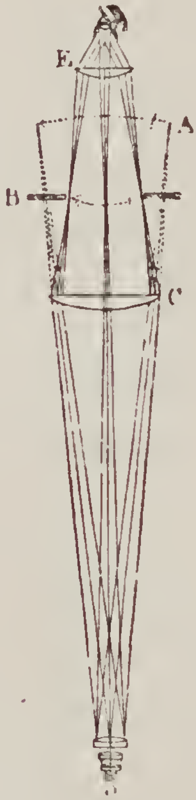


Fig. 30.

Fig. 29.—Students' Compound Microscope, as constructed by Messrs Smith and Beck. A, stand, or support; *b* mirror; *c* diaphragm, or stop; *d* stage-plate for holding the object to be examined; *e* fine adjustment screw; *f* object-glass, or that next the object, achromatic—*i.e.*, not producing colour; *g* the brass sheath in which the body of the instrument is moved by the hand, so as to be adapted to the object; *h* the eye-piece, or that to which the eye of the observer is applied.

Fig. 30.—Diagram to show the principle of the compound microscope. *o* the object placed below three achromatic lenses, forming together the object-glass. Three rays of light proceeding from different parts of object reach the plano-convex lens *c*; and in place of going to *a*, so as to form an image there, are broken or refracted, so as to form an image at *b*, where the diaphragm is. This image is seen by the eye of the observer through the lens *e*. The two lenses *e* and *c* form the eye-piece.

observer is applied. The body of the instrument can be moved upwards and downwards by the hand, as it slides in a circular brass sheath *g*—this gives what is called the coarse adjustment; and when it is brought near the object, it can be accurately adjusted to its proper focus by the screw *e*, which is called the fine adjustment screw.

This is a comparatively cheap instrument for students; and although it wants many of the conveniences connected with larger instruments, still it will answer well for the prosecution of researches into vegetable structure. In fine microscopes, the coarse adjustment, in place of being made by the hand, is accomplished by means of a rack and pinion; the stage also is moved in all directions by screws; the mirror can be moved about more freely; and the whole instrument is made so as to be placed in a horizontal position if required.

The diagram (fig. 30) is meant to show the action of the compound microscope. It represents the body of the instrument, with the object-glass at the lower end, composed of three compound achromatic lenses (fig. 31, *a*), each consisting of a double convex lens, made of plate or crown glass, and a plano-concave lens (fig. 31, *b*), made of flint-glass. It is therefore denominated a triple achromatic object-glass, or objective. The eye-pieces at the upper extremity, consist of two plano-convex lenses, one at *e* (fig. 30), called the eye-glass, and the other at *e*, called the field-glass, with a diaphragm or dark stop at *b*. The object *o* is represented by a line below the object-glass. The rays of light reflected from the object, or transmitted through it from the mirror, pass through the achromatic lenses. The course of the light is marked by three rays drawn from the centre, and three from each end of the object *o*. These rays, if allowed to proceed, would form an image of the object at *a*; but when they reach the field-glass *c*, they are made to converge and meet at *b*, where the diaphragm is placed so as to stop all the rays except those required to form a perfect image. Thus there is a distinct image of the object at *b*, which is viewed, as if it were an original object, by the eye of the observer placed at the eye-glass *e*. In the compound microscope, therefore, the object is not viewed directly through a lens, or series of lenses, but an

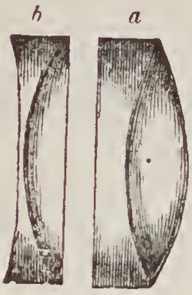


Fig. 31.

Fig. 31 represents the construction of an Achromatic Lens. *a* is an achromatic lens, consisting of a double convex lens made of plate or crown glass, and a plano-concave made of flint-glass; *b* is a section of the plano-concave lens, into which the double convex lens is fitted.

image of it is formed by one set of lenses, and this image is viewed as an original object by another lens. Bodies may be viewed through the microscope either as opaque objects, by light thrown upon them through the medium of a lens; or as transparent objects, by light transmitted through them from the mirror. In the latter case, very thin transparent sections must be made and put on a piece of thin plate-glass; some water is added, and they are then covered with very thin pieces of crown or plate glass, and the light is thrown on them by the mirror below the stage.

III.—ON THE GROWTH OF THE YOUNG PLANT.

The plant in its embryo or youngest state consists entirely of cells. In the case of flowering plants, it is contained in the seed, and along with it there is a store of nourishment for its future growth. This nutritive matter is in some cases incorporated with the young plant as in the bean and pea, the large fleshy lobes of which are part of the young plant; in other cases it is separate from the young plant, as in the coco-nut and wheat. In fig. 32 there is a representation of part of the eatable portion of the coco-nut, with the small embryo plant lying in a cavity at the top. This cavity is in the flesh of the nut, immediately below the hole in the hard shell. The little plant weighs only a few grains, while the nourishing matter weighs many ounces. In palms generally the young plant occupies a small part of the seed, and the nourishment is abundant, although sometimes, as in the date and the ivory palm, very hard. In the grains of wheat, barley, and oats, the young plant is minute, while the starch and glutinous matter stored up along with it is large. Fig. 33 represents a grain of oats, *o t* being its covering, *c g r* the young plant, with its root, stem, and leaves, and *a* the mass of nourishment laid up for the use of the young plant, and not incorporated with it.

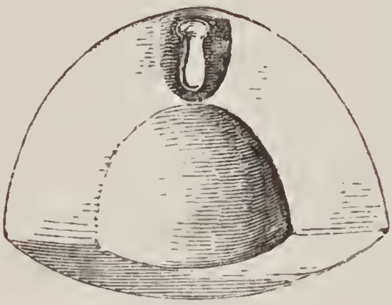


Fig. 32.

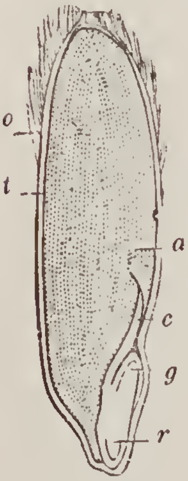


Fig. 33.

When the seed is placed in favourable cir-

Fig. 32.—Section of part of the Coco-nut Seed, showing the young plant in a cavity at one end, quite separate from the nourishing matter around.

Fig. 33.—Grain of Oats (*Avena sativa*). *o t* its coverings; *c g r* young plant; *c* being its seed leaf; *g* the young bud of the stem; and *r* part of the axis whence the root proceeds; *a* store of nourishment, called albumen.

cumstances, the little plant begins to sprout or germinate. In order that this process may take place, it is necessary that moisture, heat, and air should be present, and it is also important that the plant at first should be excluded from direct light. The supply of these requisites must be properly regulated, and in doing so the nature of the soil must be attended to. One of the most important operations for enabling grain to grow and give abundant produce is draining. Undrained soil, from having much moisture, is cold, is deficient in the supply of air, and prevents the constant renewal of food to the roots. Draining carries away superabundant moisture, allows a constant supply of fresh fluid nourishment to penetrate through the soil at the roots, permits the access of air and heat, and thus materially contributes to the health and vigour of the crops. The soil must therefore be prepared and fitted for the seed, otherwise, as far as regards useful and nutritious plants, the sowing will be unproductive. "Man must gain his bread by the sweat of his brow" (Gen. iii. 19). The garden of the sluggard no doubt produces plants, but they are not such as are fitted for the nourishment of man. "I went by the field of the slothful; and, lo, it was all grown over with thorns, and nettles had covered the face thereof" (Prov. xxiv. 30, 31). "As the sluggard will not plough, he shall beg in harvest, and have nothing" (Prov. xx. 4).

When seeds are sown naturally, they have only a slight covering of soil, and if they happen to become deeply buried, the proper access of air is prevented, and their sprouting is retarded. It is of importance that man in sowing seeds should imitate what occurs in nature. They should be placed at a moderate and equal depth. Hence the necessity for regular ploughing, in order that all the grains may be at a proper distance from the surface of the soil, and that the growth and progress of the plants may be uniform. When ploughing is irregular, the grain sinks to different depths, some plants come up before others, and they ripen at different periods,—an occurrence which tends to injure the harvest; for the ripe grain, when allowed to remain beyond a certain period, loses part of its nutritious qualities, and thus the produce of the field is diminished in value. Seeds often lie long dormant, especially when placed too deep in the earth, and it is only when the soil is turned up and air admitted that they spring up. Many are the instances of seeds retaining vitality long, when buried in the ground, under certain conditions. The seeds of white clover may remain in the soil for many years, and yet when brought near the surface, so as to be within the action of the air, germinate freely. After the great fire of London, numerous plants sprung up, the seeds of which would appear to have lain long in the ground. While seeds naturally preserved in the soil and in peat mosses retain their vitality, it is not easy for man to imitate these conditions. All the stories about the germination of mummy-wheat are doubtful. There does not appear to be a single authentic case of such an occurrence having taken place. No doubt there are numerous fields of what is called mummy-wheat over the country, but none can be proved by unimpeachable evidence to be the produce of grains of the same age as the mummies.

The various phenomena connected with the sprouting of the seed are well seen in the malting of barley. The grain is exposed to moisture, heat, air, and is kept in comparative darkness. It is precisely in circumstances fitted for its sprouting, or *germination*, as it is called. A very marked change takes place in the contents of the grain. The starch, which is insoluble in water, and unfit for the nourishment of the plant, is converted into sugar, which is soluble, and easily taken up by the cells of the plant as food. The young roots are first protruded, and then the stem rises, surrounded by a leaf called a cotyledon, or seed-leaf. If the barley was allowed to grow, the whole of the sugar would be used by the plant. But man wishes to get the sugar, and he therefore stops the plant in its growth by drying it, and thus makes malt. The progress of growth in the oat is seen in fig. 34, which represents the embryo at one end of the grain, the curved dotted lines marking the dimensions of the grain. The letter *r* indicates the young roots passing through sheaths *co*, and covered with little cellular hairs, ready to take up fluid nourishment; *c* is the cotyledon—*i.e.*, the seed-lobe or seed-leaf; *g* is the young stalk or stem rising upwards. In the Indian corn (fig. 35) the same parts are seen—the roots, the cotyledon *c*, united to the grain by a stalk *t*, and the young stem-leaves *g*.

In many plants the embryo, in place of having only one cotyledon, as in grasses and palms, has two. These cotyledons, during the sprouting of the plant, either rise above ground, and appear as temporary leaves of a peculiar form, as is seen in the lupin; or they remain below ground as fleshy lobes, and are gradually absorbed, as in the bean and pea (fig. 36). In fig. 36 a representation is given of the sprouting of the pea, where *c c* are the cotyledons, *r* is the radicle or young root, *g* the young stem-

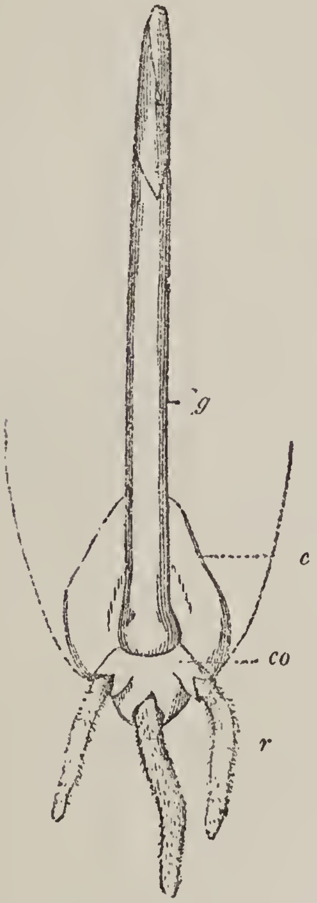


Fig. 34.

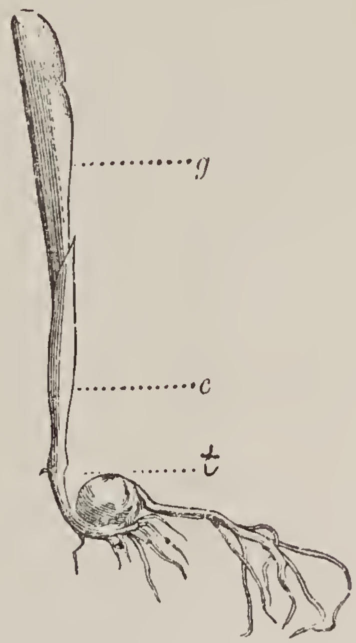


Fig. 35.

Fig. 34.—Germination or sprouting of the grain of oats. *r* roots passing through sheaths *co* ; *c* cotyledon ; *g* the first leaves of the plant. The plant is monocotyledonous, or has only one cotyledon.

Fig. 35.—Germination or sprouting of the grain of maize, or Indian corn. *t* stalk supporting the cotyledon *c* ; *g* the first leaves of the plant. It is monocotyledonous.

bud. Fig. 37 represents the germination of the common haricot, where *r* is the root

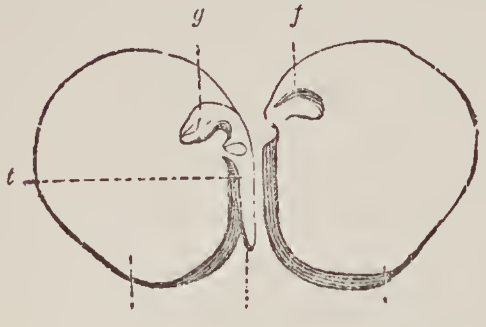


Fig. 36.

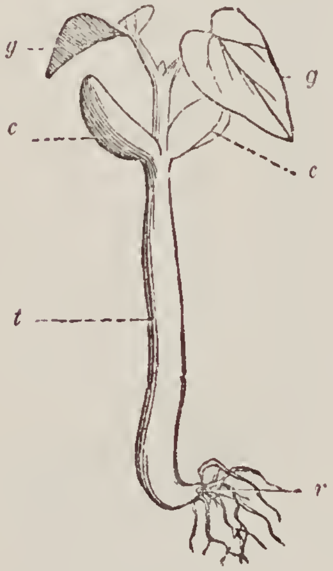


Fig. 37.

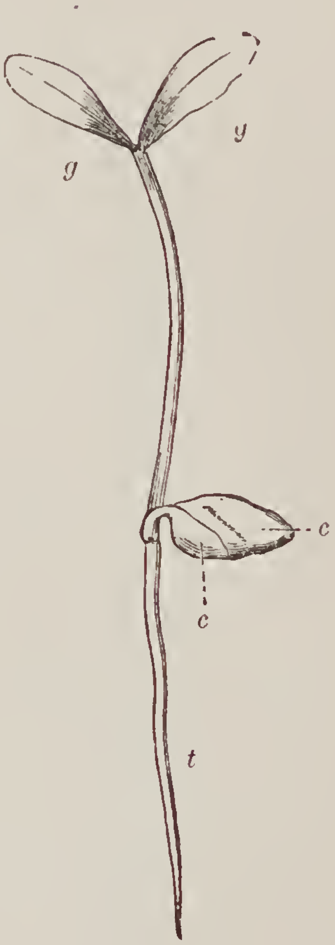


Fig. 38.

of the young plant, *t* is the stalk supporting

Fig. 36.—Embryo of the Pea (*Pisum sativum*). The cotyledons *c c*, or seed-lobes, are fleshy, and remain below ground, in other words, are hypogeal. The radicle *r* protrudes through an opening, and is the first portion of the embryo which appears during germination. The plumule, gemmule, or first bud *g*, afterwards appears and rises upwards to form the ascending axis. The common axis *t*, whence the radicle and plumule proceed, is united to the cotyledons by a short petiole; *f*, a small depression in one cotyledon, where the young bud *g*, lay.

Fig. 37.—Germination or sprouting of the haricot (*Phaseolus vulgaris*).

the two cotyledons *c c*, and *g g* are the first proper leaves of the plant. In the orange (fig. 38), the cotyledons *c* remain below ground in the seed *t;* such is also the case in the bean and pea, in which the cotyledons form the great bulk of the seed. In plants which have no flowers, as ferns, mosses, sea-weeds, and fungi, the little germs are simple cells without any cotyledon, which send out cellular roots from various parts of their surface. In fig. 39 there is a representation of the germs of a flowerless plant, consisting of single cells, with tapering projections forming the roots. There is here no distinction of parts, as in the embryo or germ of flowering plants.

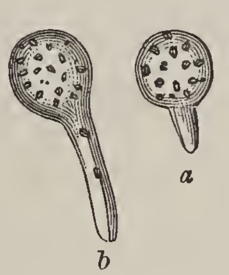


Fig. 39.

It will thus be seen that, according to the nature of the embryo or young plant, the whole vegetable kingdom can be divided into,—1. Flowering plants having one cotyledon, called Monocotyledonous plants (figs. 34, 35); 2.

t stalk supporting two cotyledons *c c; g g*, the first leaves. The plant is dicotyledonous.

Fig. 38.—Germination or sprouting of the orange. *c*, the two cotyledons enclosed in the seed *t*, and remaining underground. The plant is dicotyledonous.

Fig. 39.—Germinating spores or germs of a species of Liverwort (*Marchantia polymorpha*), in different stages of growth. A small cellular protuberance first appears *a*, which ultimately elongates as seen at *b*. In the progress of development roots are produced, and a cellular expansion called a thallus, bearing fructification.

Flowering plants having two cotyledons, or Dicotyledonous plants (figs. 37, 38); 3. Flowerless plants without cotyledons, Acotyledonous plants, fig. 39).

Many are the illustrations in the Bible taken from the sowing and springing of the seed, and from the nature of the soil on which it falls. The seed of the Word must be sown in good soil, prepared by the Great Husbandman; and, when watered by the dew of His Spirit, it springs up and bears fruit to the glory of God. The growth is slow and gradual; "first the blade, then the ear, then the full corn in the ear" (Mark iv. 28). It may lie dormant for a time, and in darkness, but the spark of life will ultimately break forth. In the parable of the sower (Matt. xiii. 3; Mark iv. 3; Luke viii. 5), the various kinds of soil are employed to illustrate the heart of man in its natural and in its renewed state. In the former, it is hard and cold, and is not prepared for the good seed: the seed does not sink into it, or it is choked by weeds, or it lacks the dews and the atmosphere of heaven; and hence it brings no fruit to perfection. In the latter, there is the preparation of the Spirit, nourishment from on high, the former and the latter rain, and fruit, in some thirty, in some sixty, and in some an hundredfold. The former and the latter rain are often referred to as promoting the sprouting of the seed and the growth of the plant (Jer. v. 24; Hos. vi. 3; Joel ii. 23). The first of these rains took place in Palestine after the seed was sown, and the second when the corn was nearly ripe and harvest was at hand.

In John xii. 24, Christ says, "Except a corn [grain] of wheat fall into the ground and die, it abideth alone; but if it die, it bringeth forth much fruit." We see an apt illustration here. The great bulk of the grain of wheat (fig. 40) is composed of nutritious matter (fig. 41 *a*), separate from the little plant or embryo (fig. 41 *b*). This matter must all be changed and dissolved, in order that the plant may spring. Unless it dies, and undergoes solution, there can be no nourishment conveyed. Again, the sprouting of the grain is taken by St Paul as an emblem of the resurrection. The bare or naked grain which is sown is not quickened except it die; and out of the corruption and dissolution which it undergoes there springs up, by a wondrous metamorphosis, the blade of wheat, or of

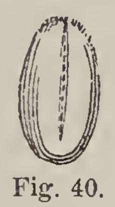


Fig. 40.

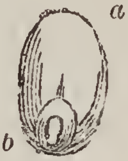


Fig. 41.

Fig. 40.—Grain of wheat, seen on its inner surface.

Fig. 41.—Grain of wheat, seen on its outer surface, with the small embryo *b*, at one side; all the rest of the grain being occupied with nourishing matter *a*, called albumen, which is dissolved, and dies.

some other grain. "So also is the resurrection of the dead; it is sown in corruption, it is raised in incorruption: it is sown in dishonour, it is raised in glory: it is sown in weakness, it is raised in power: it is sown a natural body, it is raised a spiritual body" (1 Cor. xv. 42-44).

> "Christ out of ruin brings forth strength and beauty;
> Yea, life and immortality from death."

John Bunyan says, "There is a poor, dry, and wrinkled kernel cast into the ground; and there it lieth, swelleth, breaketh, and one would think, perisheth. But, behold, it receiveth life, it chippeth, it putteth forth a blade, and groweth into a stalk. Then also appeareth an ear; it also sweetly blossoms, with a full kernel in the ear. It is the same wheat; yet, behold, how the fashion doth differ from what was sown! And our *brawn* will be left behind when we rise again. The body ariseth as to the nature of it—the selfsame nature; but, as to the manner of it, how far transcendant! 'The glory of the terrestrial is one, and the glory of the celestial another.'"

When we look at the bare grain, we call it wheat; when we contemplate the blade opening up, we still call it wheat; we·know that it is the plant in different stages. God gives to each kind of grain, as wheat, oats, and barley, a body as it has pleased Him—the body being the green clothing which appears as the blade. So the believer's body is committed to the dust and decays, but out of it at last is to arise a glorious body; and, as the young plant takes up all the decayed part of the grain, and transforms it into a beauteous form, so, when the new and glorious body rises, it may be said that "mortality is swallowed up of life" (2 Cor. v. 1-4); that corruption has been changed into incorruption. The believer has been clothed upon with his body which is from heaven, in the same sense as Christ speaks of God clothing the grass of the field (Matt. vi. 30).

In Matt. vi. 28, our Saviour says, "Consider the lilies how they grow." We fear this is not often done. We are content to look at the plants when grown, but we do not examine *how* they grow, from the embryo up to the perfect state of flowering and fruiting. We shall understand the illustration better, and see more of the providential care of God, if we attend to the development of cell after cell by slow degrees, the formation of vessels, the arrangement of coloured cells, the absorption of fluids, and the various processes of nutrition and reproduction.

In Ps. xcvii. 11, it is said, "Light is sown for the righteous, and gladness for the upright in heart." Here light and gladness are regarded as seeds sown in the earth for the righteous. Let us trace out the illustration by reference to the phenomena connected with the sowing of seed. As in the case of the seed, light and gladness are placed in the earth. They are much obscured by the earthy covering; light is mixed with darkness, as it were, and gladness with sorrow. The believer sees through a glass darkly, and has many tears and woes. But light and gladness are there, and will spring up. The more slightly they are covered by the earth and the things of the earth, the more readily will they develop themselves. If they are deep in the earth, their progress is hindered; they require the atmosphere of heaven to bring them out. "Who is he that walketh in darkness, and hath no light; let him trust in the name of the Lord, and stay himself upon his God" (Isa. l. 10). This is but the sowing time; at eventime there shall be light. Then shall light and gladness, freed from earth and all its encumbrances, spring up in bright effulgence and fulness of joy, and the seed sown in earth shall expand in all the blossoms and fruits of heaven.

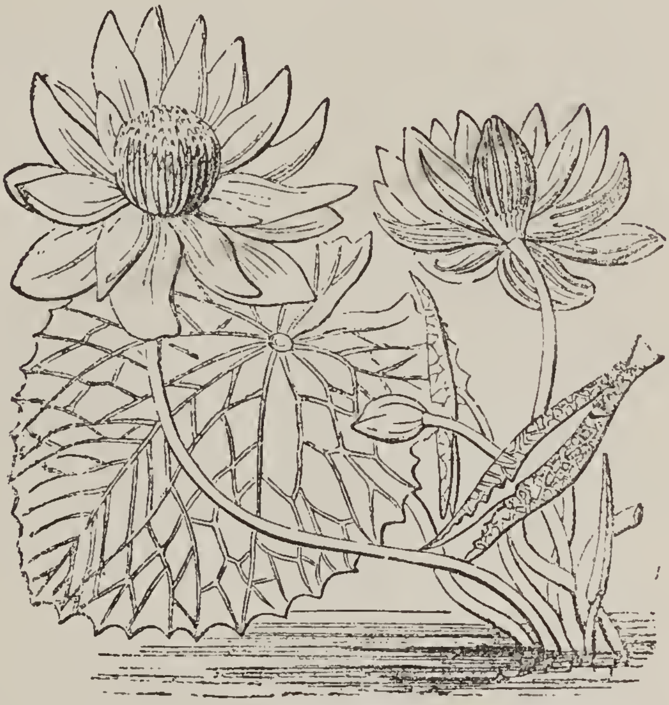


Fig. 42.

The sowing of the seed in the mud of rivers may perhaps be alluded to in the following words: "Cast thy bread upon the waters, for thou shalt find it after many days" (Eccles. xi. 1). The seeds of a kind of water-lily, called the Lotus-lily (fig. 42), are used in the manufacture of bread, owing to the quantity of starch and gluten which they contain. These

Fig. 42.—*Nymphæa Lotus*, one of the plants to which the name of Lotus was given by the ancients. Its seeds were used to form bread, and its roots are also eaten. It is considered to be the lily of the Old Testament.

seeds are enveloped in clay, and are thrown into the water, so that they sink in the mud.* There they germinate; and after many days, the plants appear above the water, bearing flowers and fruit. When ripe, the seeds are again employed as articles of food. The passage in Isaiah xxiii. 3—"And by great

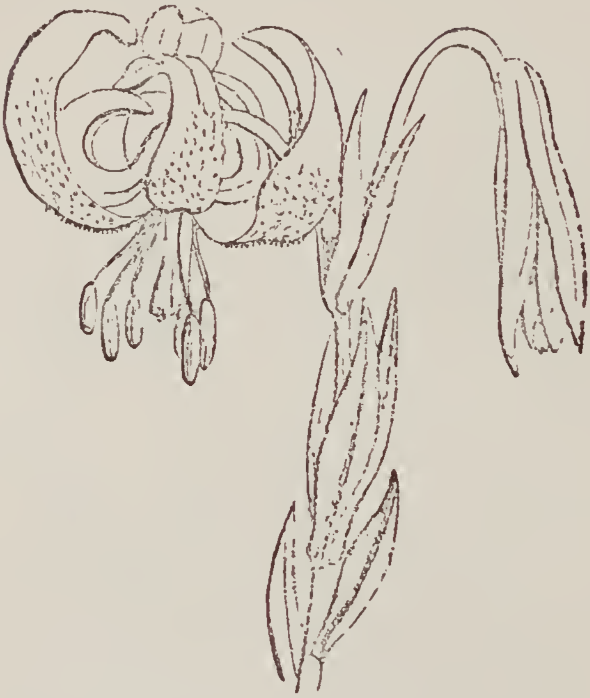


Fig. 43.

Fig. 43.—*Lilium Chalcedonicum*, the scarlet Martagon Lily. The lilies of the field of the New Testament.

[*] This mode of sowing, according to Royle, is to the present day practised by certain tribes in the Indian peninsula. *Nelumbium speciosum* or the sacred water bean, is the Egyptian Lotus represented on Egyptian and Indian monuments. Its fruit, which is edible, is supposed to have constituted the Pythagorean bean. This plant used to abound in the Nile, but it has now disappeared. It is not uncommon in Eastern countries.

waters the seed of Sihor, the harvest of the river, is her revenue"—is by some supposed to refer to the Lotus-lily which is still held sacred in the East. It is related that one of the benighted natives of Nepaul, upon entering Sir William Jones's study, made prostrations before the flowers of this plant, which happened to lie there for examination. The plant shown in fig. 42 is considered by Royle as the Shushannah or Lily of the Old Testament, so frequently referred to in the Song of Solomon; while the lilies of the field, noticed in the New Testament, are probably the scarlet Martagon Lily, or *Lilium Chalcedonicum* (fig. 43).

IV.—ON THE STRUCTURE AND FUNCTIONS OF THE ROOT.

The root is the first part of the young plant which protrudes from the seed (fig. 36 *r*, p. 48). It descends into the ground in order to fix the plant and to derive nourishment. On account of its downward tendency, the name of Descending Axis is sometimes applied to it. The cells situated near the extremities of the minute fibrils of the root, are those which are chiefly concerned in taking up nourishment from the soil. They are represented on a magnified scale in fig. 44, *sp*. The other cells of the root are indicated by *c c*, and these pass gradually into dotted vessels *v*.

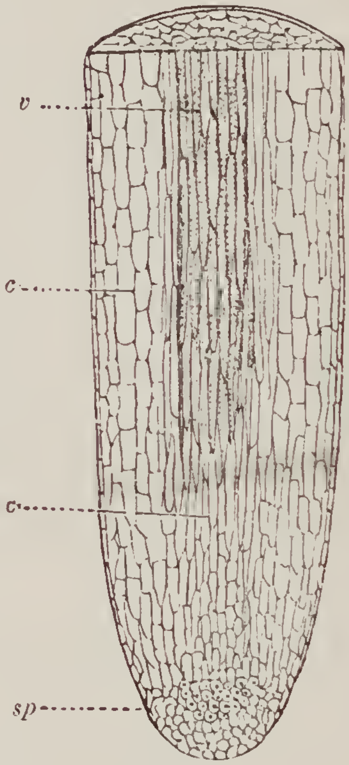


Fig. 44.

As plants are fixed to a spot, their food must be always within reach; and it is requisite that the roots should have the power of spreading, so as to secure renewed supplies of nutriment. A beautiful provision is made for this by the elongation of the roots taking place at their extremities, so that their advancing points are enabled easily to accommodate themselves to the nature of the soil in which the plant grows. If roots had increased by additions throughout their whole extent in the same way as stems, they would, in many instances, when meeting with an impenetrable soil, have been twisted in such a way as to unfit them for the free transmission of fluid. But by the mode of

Fig. 44.—Vertical section of a rootlet of an Orchis, much magnified; *sp*, the minute cells at the extremity, called sponglets; *cc*, the other cells of the root; *v*, dotted vessels.

lengthening at the point, they insinuate themselves easily into the yielding part of the soil, and when obstacles are presented to their progress, they wind round about them, until they reach a less resisting medium. They are thus also enabled to move from one part of the soil to another, according as the nourishment is exhausted.

The root, in its growth, keeps pace with the development of the stem and its branches. As the stem shoots upwards and produces its leaves, from which water is constantly transpired, the roots continue to spread, and to renew the delicate cells and fibrils which absorb the fluid required to compensate for that lost by evaporation, or consumed in growth. There is a constant relation between the horizontal extension of the branches and the lateral spreading of the roots. In this way the rain which falls on a tree drops from the branches on that part of the soil which is situated immediately above the absorbing fibrils of the roots. It is not by watering a tree close to the trunk that it will be kept in vigour, but by applying the water on the soil at the part corresponding to the ends of the branches. "We have here," says Roget, "a striking instance of that beautiful correspondence which has been established between processes belonging to different departments of nature, and which are made to concur in the production of such remote effects as could never have been accomplished without these preconcerted and harmonious adjustments."* If the roots are not allowed to extend freely, they exhaust the soil around them, and do not receive a sufficient supply of food. The plants in such a case, deprived of their proper means of support, become stunted and deformed in their appearance.

If we wish trees to be firmly rooted, we must allow the branches to spread freely. When they are so planted that the branches and leaves of contiguous trees do not interfere with each other, and thus all parts are exposed to air and light equally, the roots spread vigorously and extensively, so as to fix the plants firmly in the soil, and to draw up copious supplies of nourishment. But in crowded plantations, where the branches are not allowed freedom of growth and exposure, and the leaf-buds are consequently either arrested or feebly developed, the roots also are of necessity injured. They do not spread, and the trees are liable to be blown over by the wind; they exhaust the soil in their vicinity, circumscribed by the roots of the trees around; their functions become languid, and thus they react on the stem and branches, so that the additions to the wood are small, and the timber is of bad quality. In such a plantation, we may see a marked difference between the trees on the outside and those in the centre; the former, having their branches and leaves fully exposed on one side, grow with comparative vigour, and form excellent timber, on that side of the stem where light and air are admitted; while the latter, hemmed in on all sides, are *drawn up* like bare poles, producing a small amount of ill-conditioned wood. A crowded plantation, in which the trees are allowed to increase in size, until they interfere with each other, cannot be easily reclaimed; and every attempt at thinning is accompanied with the risk of exposure to the blasts, which speedily level trees having no firm hold of the soil.

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* Roget's Bridgewater Treatise.

The roots of plants should not be disturbed at the time when they are in active operation. During the season of growth, when the branches and leaves are pushing forth, the roots are also developing their rootlets, and constantly renewing their delicate absorbing extremities. Any attempt to transplant at this period is attended with serious injury, because those minute fibrils are destroyed by means of which the fluid transpired by the leaves is restored. It is only in autumn, when the rootlets cease to grow, and absorption becomes languid, or in early spring, before their activity begins, that transplanting can be prudently conducted. In transplanting large trees, it has been customary to cut the roots all round at some distance from the trunk the season before they are removed. Thus an opportunity is afforded for the production of new fibrils, which, after transplantation, are ready to absorb nourishment.

Roots in general descend into the soil at once; but in some cases they proceed from different parts of the stem, and thus are in the first instance aerial. The Banyan tree of India (fig. 45) exhibits these roots in a remarkable manner. They proceed from all parts of its stem and branches, and ultimately reach the soil, forming numerous stems which support this wide-spreading tree. The famous Nerbudda Banyan has 300 large and 3000 small stems, and it is said to be capable of sheltering 7000 men.

> "Such, too, the Indian fig, that built itself
> Into a sylvan temple, arch'd aloof
> With airy aisles and living colonnades."—MONTGOMERY.

Or, as Milton describes it :—

> " The fig tree ; not that kind for fruit renown'd ;
> But such as at this day to Indians known
> In Malabar and Deccan, spreads her arms,
> Branching so broad and long, that in the ground
> The bending twigs take root, and daughters grow
> About the mother-tree, a pillar'd shade,
> High over-arch'd, with echoing walks between."

In some parts of India bridges are made by uniting the aerial roots of species of Ficus, growing on either side of a stream.

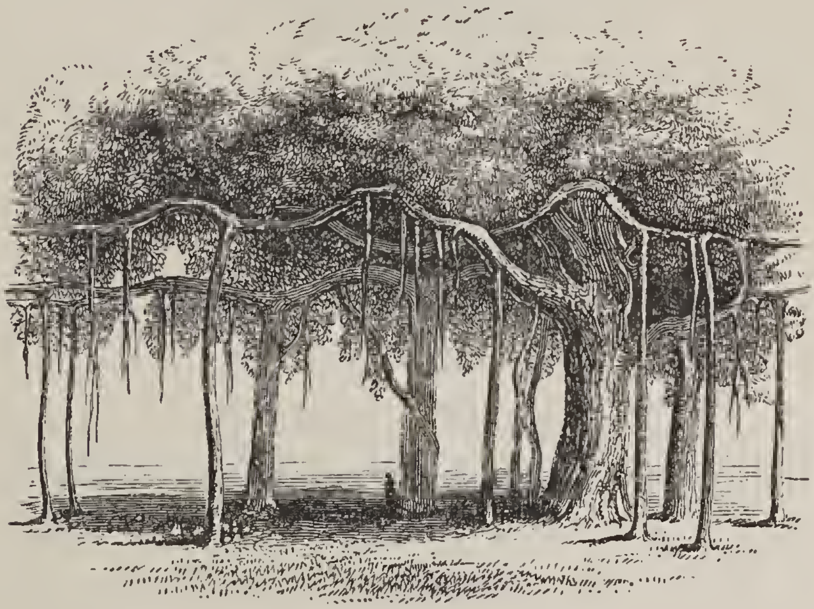

Fig. 45.

The Screw pine (fig. 46), is another instance of a plant giving out aerial roots. These sup-

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Fig. 45.—*Ficus indica*, the Banyan tree (belonging to the same genus as the Fig), sending out numerous adventitious or aerial roots, which reach the soil, and prop the branches.

port the plant like wooden props. A large tree of this kind, in the Palm-house of the Edinburgh Botanic Garden, had one of its branches injured many years ago, and at the point of injury a root appeared long before its time, and thus supported a branch which would otherwise have been cut off. This circumstance is mentioned by Miss M'Nab, in her Lessons from Bible Plants, as having struck Dr Chalmers very forcibly on one of his visits to the garden.* The Mangrove (fig. 47), also exhibits similar supports.

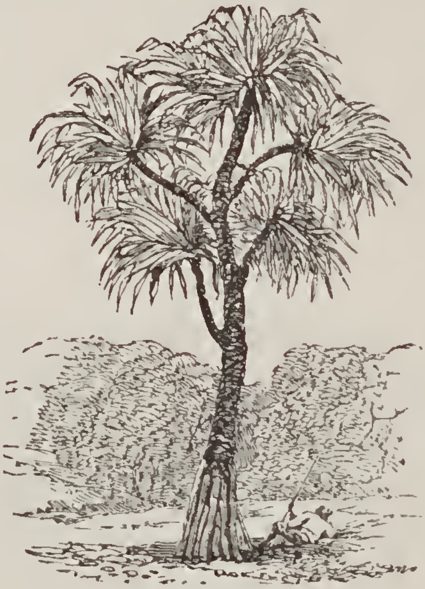

Fig. 46.

When roots do not extend much, they are

Fig. 46.—*Pandanus odoratissimus*, the Screw pine, giving off numerous aerial roots near the base of its stem.

* Botany of the Bible, by Miss M'Nab.

sometimes provided with reservoirs of nourishment which supply the means of growth during a certain period. This is seen in the case of terrestrial orchids (figs. 48, 49). These reservoirs or tubercules constitute the Salep of the Turks, which is used as food. In dry soils roots are sometimes unable to spread from want of moisture, and form bulb-like appendages so as to lay up a store of nourishment. In seasons of drought also, a similar occurrence may take place. In the orchids of warm climates, in

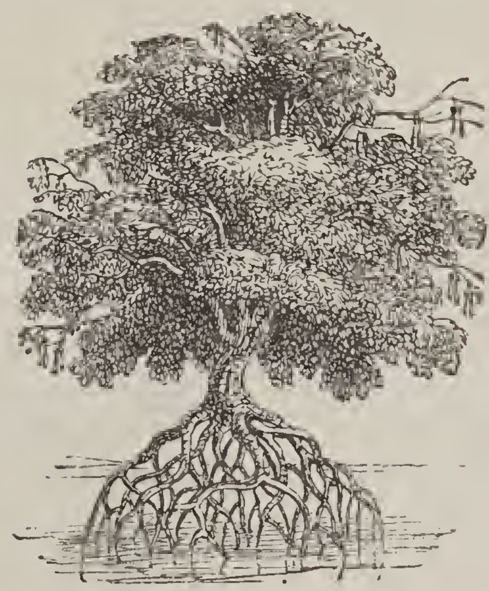

Fig. 47.

Fig. 47.—*Rhizophora Mangle*, the Mangrove tree, supported, as it were, upon piles by its numerous roots, which raise up the stem. The plant grows at the muddy mouths of rivers, in warm climates. Mangroves are constituted by Avicennias and Rhizophoras. Avicennias have asparagus-like under-ground stems, which send up innumerable young shoots whenever the main stem is disturbed. Rhizophoras send out aerial roots, which preserve the trees from falling after the terrestrial roots have lifted them high above the original level of the ground.

place of thickened roots, there are large bulb-like stems which serve the same purpose. These orchids, which are often called air-plants or epiphytes, send out roots into the air, and attach themselves to the stems and branches of trees. They do not push their roots into the interior of the plants, but they are nourished by the moisture around them, and by the decay of matter on the outside of the branch. These epiphytes are seen in the Aerides, Vandas, and Saccolabiums of the damp and hot parts of

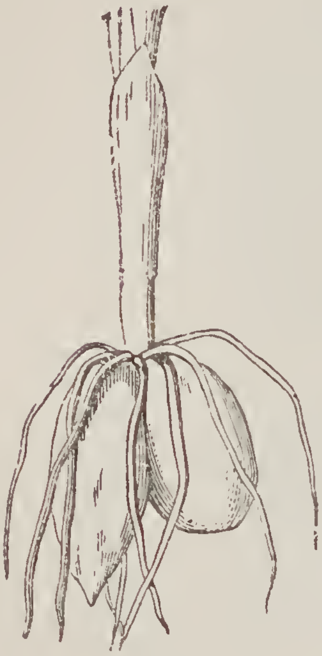

Fig. 48.

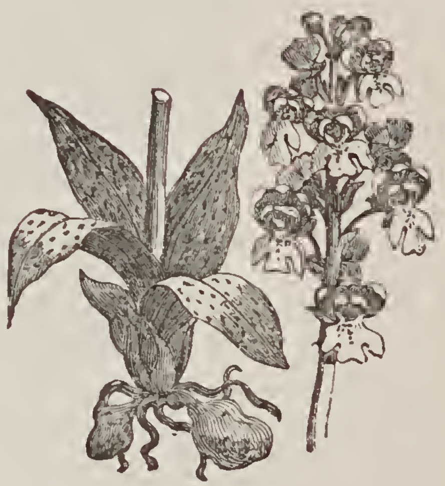

Fig. 49.

Fig. 48.—Roots of Orchis; some of them are slender and absorb nutriment, while two of them are thick, fleshy tubercules, which contain a reservoir of food, and constitute salep.

Fig. 49.—Orchis; showing tubercules or tuberous roots, which contain a gummy matter called Bassorin.

India; Schomburgkia of the woods of Honduras and Guiana; superb Lælias of South America; many-flowered Epidendrums of the South American Islands, and the beautiful and sweet-smelling Stanhopeas (De Vriese). Some plants send their roots or suckers into the substance of other plants either dead or living, and derive their food entirely from them. Such are called *parasites,* and they may be illustrated by moulds (fig. 50); by fungi which grow on the decaying stumps of trees, and by those which cause diseases in growing crops; by dodder (fig. 51), which injures flax and clover by living on their juices; and by broom-rapes, and scale-wort, as well as by the gigantic Rafflesia of Java (fig. 52). Some of these parasites have no leaves; some bear brown scales; while others, as the mistletoe (fig. 53), have green leaves, which elaborate the juices derived from the stock by exposing them to the air and light. The study of the growth of parasitic fungi is a subject of great importance,

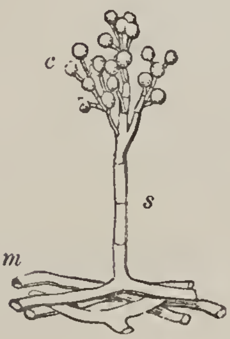

Fig. 50.

Fig. 50.—A species of mould-fungus (*Botrytis*), magnified. Below, there are root-like filaments *m*, constituting the spawn. These insinuate themselves into the tissues of living plants, and act as parasites, drawing nourishment from the tissues, and ultimately destroying the plants. The stalk *s* consists of cells bearing rounded reproductive cells or spores *c*.

as many diseases in plants, animals, and man appear to be either caused or modified by them. Dry-rot in wood, for instance, is attributed to the attack of a fungus; so also are certain diseases of the skin and mucous membrane in man and animals.

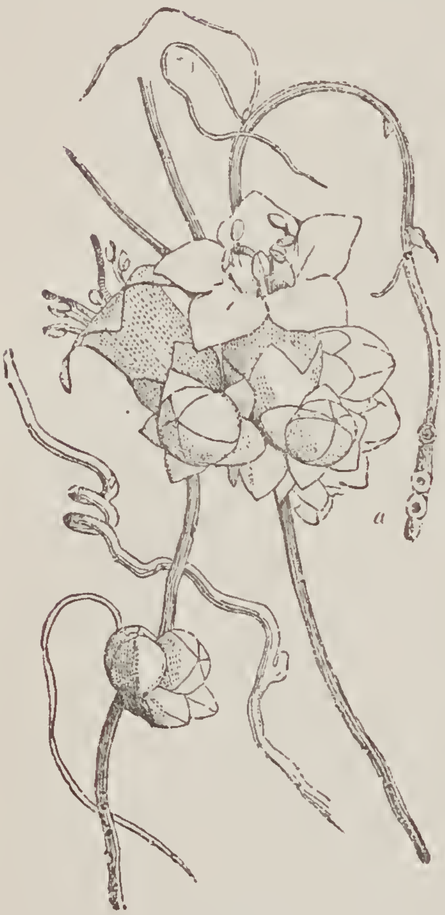

Fig. 51.

The exhaustion of the soil by the roots of plants affords an explanation of the phenomenon called *fairy rings*, consisting of circles of dark green grass seen in old pastures.* These have been traced to the successive generations of certain fungi spreading from a central point. "The soil which has once contributed to the support of these fungi,

Fig. 51.—Cuscuta or Dodder, a parasite which first grows in the usual way, from seed, with its roots in the ground, but ultimately twines round other plants, and becomes attached to them by means of the rounded suckers represented on the slender branch *a* in the figure.

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* Wollaston, Phil. Trans. for 1807, p. 133; Dr James Hutton on certain natural appearances of the hill of Arthur's Seat, near Edinburgh (Trans. Roy. Soc. Edin., ii. 3).

becomes exhausted or deteriorated with respect to the future crops of the same species, and the plants therefore cease to be produced on these spots; the second year's crop consequently appears in the space of a small ring, surrounding the original centre of vegetation; and in every succeeding year the deficiency of nutriment on one side necessarily causes the mycelium (fig. 50 *m*) to extend itself solely in the opposite direction, and thus the circles continually proceed by annual enlargement from the centre outwards. An appearance of luxuri-

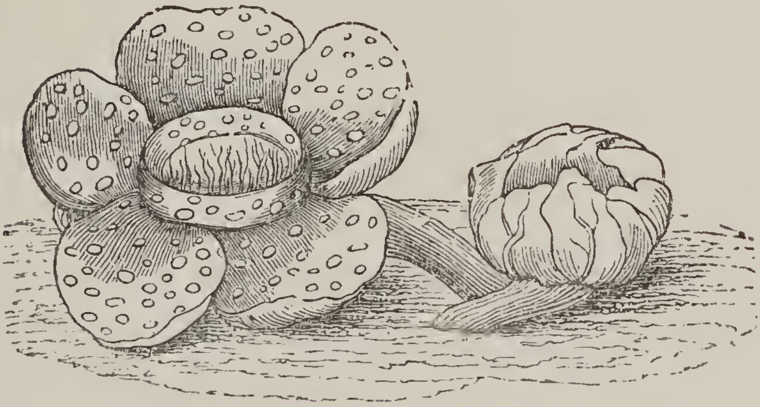

Fig. 52.

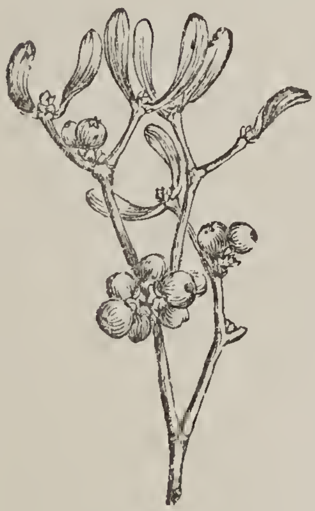

Fig. 53.

Fig. 52.—*Rafflesia Arnoldi*, a parasitic plant of Sumatra. The flower is three feet in diameter. It grows attached to the stem of a climbing Cissus.

Fig. 53.—*Viscum album*, the Mistletoe, a green-leaved parasite, deriving nourishment from the plants to which it is attached.

ance of the grass follows as a natural consequence; for the soil of an interior circle will always be enriched and fertilised with respect to the culture of grass by the decayed fungi of the preceding year's growth. It often happens, indeed, during the growth of these fungi, that they so completely absorb all nutriment from the soil beneath, that the herbage is for a time totally destroyed, giving rise to the appearance of a ring bare of grass surrounding the dark ring; but after the fungi have ceased to appear, the soil where they had grown becomes darker, and the grass soon vegetates again with peculiar vigour. When two adjacent circles meet, and interfere with each other's progress, they not only do not cross each other, but both circles are invariably obliterated between the points of contact; for the exhaustion occasioned by each obstructs the progress of the other, and both are starved. It would appear that different species of fungi often require the same kind of nutriment; for, in cases of the interference of a circle of Agarics with another of Puff-balls, still the circles do not intersect one another; the exhaustion produced by the one being equally detrimental to the growth of the other, as if it had been occasioned by the previous vegetation of its own species."* Way finds that the fungi forming fairy rings (such as *Agaricus oreades* and *graveolens*) contain a large quantity of phosphoric acid and potash in their composition; and hence, as these are required for the nourishment of grass, the growth of fungi destroys the pasture at first. Subsequently, however, when the fungi decay, they restore to the soil valuable manure, which causes a vigorous growth of herbage.†

The root supplies many Scripture illustrations, both as fixing the plant and as drawing up nourishment. Thus, in Hosea xiv. 5, Israel, when restored, is said to "cast forth his roots as Lebanon," or the cedar of Lebanon, implying great vigour as well as firmness and strength. This tree (fig. 66, p. 85) is remarkable for its spreading roots, which extend to a great distance from the trunk, thus bearing a relation to the enormous branches. These roots fix the tree very firmly in the soil or rock, and enable it to derive a constant supply of nourishment. The streams from Lebanon furnished water to the cedar; and hence Ezekiel, when likening the Assyrian to this tree (xxxi. 4, 5), says, that the waters made him great, and that his branches became long because of the multitude of waters. The believer is "rooted and grounded in love" (Eph. iii. 17), his roots extend into the Rock of Ages (Col. ii. 7), he is watered by the dew of God's Spirit (Hos. xiv. 5), and thus it is that his root is not rottenness, nor does his blossom go up as dust (Isa. v. 24), but he brings forth fruit to the glory of God. The root being holy, so are the branches (Rom. xi. 16). If there is no root,—if, with a specious appearance, the man grows up, like the trees of a crowded forest, under an adventitious support from his fellow-men, then, when mere human props are removed, there is nothing to prevent him from falling. He may be drawn up, as it were, under the fostering care of others, and may be loud in his profession, attaining to great eminence in the world, but if the root of the matter (Job xix. 28) is not in him, then all will be ruin at last. Such an one hath no root, and dureth only for a while; but when tribulation and persecution ariseth because of the word, or when temptation comes, he falls away (Luke viii. 13; Mark iv. 17; Matt. xiii. 21). As being the source of life to His Church, Christ is sometimes likened to the root. Thus, in describing the blessedness of the latter days, Isaiah says (xi. 10), "And in that day there shall be a root of Jesse, which shall stand for an ensign of the people; to it shall the Gentiles seek; and his rest shall be glorious." In Revelation (v. 5), He is called the Root of David. Though at first He was despised and rejected by men, as a root out of a dry ground (Isa. liii. 2, 3), yet as the tree whose leaves are for the healing of the nations (Rev. xxii. 2), He shall overshadow the world, having the uttermost parts of the earth for His possession (Ps. ii. 8).

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* Roget, Bridgewater Treatise on Animal and Vegetable Physiology, i., p. 55.

† Way, on Fairy Rings in Pastures.—Journ. Eng. Agric. Soc., vii. 549.

V.—ON THE STRUCTURE, CONFORMATION, AND FUNCTIONS OF THE STEM.

The stem is the name given to that part of a plant which bears the leaves and the flowers. Some plants have very short and inconspicuous stems; others have long and conspicuous stems. In the cowslip, dandelion, and gentianella, the stem is so short that the leaves appear to arise from the root. Some stems lie along the ground, as in the iris and Solomon's seal (fig. 54); others are completely under ground, as ginger (fig. 55). The latter give off leaf-buds, which appear above ground. The banana (fig. 23, p. 32) has an under-ground stem pushing out shoots, which form temporary aerial stems or branches; so have also the asparagus, bamboo, arrow-root, and some rushes and carices. Many subterranean stems are called, in common language, roots, from which, however, they are distinguished by the leaf-buds which spring from them. Thus the potato is an under-ground stem or branch giving off buds in the form of *eyes*. The bulbs of lilies, leeks (fig. 56), tulips, crocuses, and meadow-saffron, are in reality

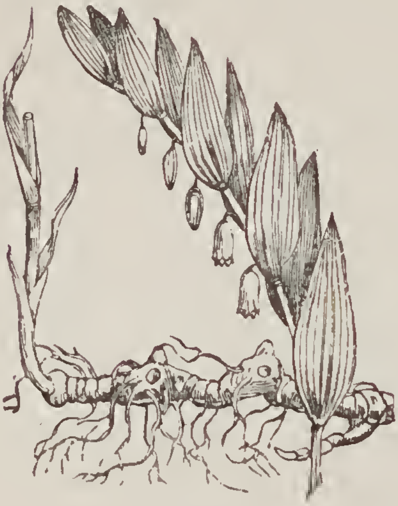
Fig. 54.

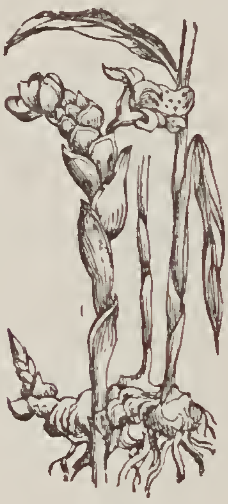
Fig. 55.

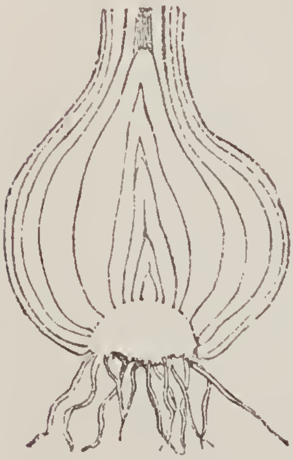
Fig. 56.

Fig. 54.—Rhizome, root-stock, or partially subterranean creeping stem of Solomon's seal (*Polygonatum multiflorum*). The scars left on the stem by the fall of the shoots, give rise to the English name of the plant.

Fig. 55 —Rhizome, or thickened creeping stem of ginger (*Zingiber officinale*), producing flowering stems and roots. This rhizome or root-stock is the part used economically and medicinally.

Fig. 56.—Tunicated bulb of leek (*Allium Porrum*), cut perpendicustems giving off buds, which are covered with scales or modified leaves.

Some stems are weak, and are supported by climbing on walls or rocks, as ivy, or by twining round some support, as convolvulus. These twining stems turn in certain definite directions. Thus the convolvulus, passion-flower, and French bean, twine from right to left, that is, to a person supposed to be in the centre of the coil, and the stem passing across his chest from his right to his left; while the hop, honeysuckle, and black bryony, twine from left to right.

Some stems die annually, others continue permanent. Of the permanent woody stems there are two marked kinds. One occurs in the trees of temperate climates generally, and is recognised on a transverse section, by the appearance of numerous woody circles with rays passing from the pith to the bark, which is separable. This is well seen in the common oak (fig. 57), where the pith in the centre is composed of cells; the circles of wood consist of woody fibres (fig. 14, p. 27), and dotted or porous vessels (fig. 16, p. 28); cellular rays extend from the pith to the bark,—the latter

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larly, showing the plateau or disc at the base whence roots proceed on one side, and scales with the growing point on the other. The outside scales are thin, while the internal ones are fleshy.

being partly fibrous and partly cellular. A section of such a stem in the first year of growth exhibits the appearance presented in fig. 58, where *m* is the cellular pith, very large; *r* large cellular rays proceeding from the pith and ending in the cellular bark, which forms the circumference. These rays divide the stem in the figure into ten wedges of woody and porous vessels; while spiral vessels *t* occur round the pith. In the second year of growth, a second set of vascular wedges is formed outside the first circle, and so on year

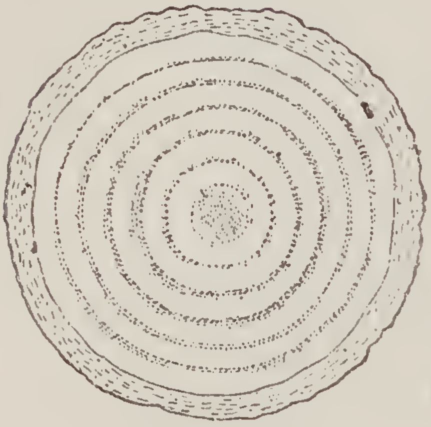

Fig. 57.

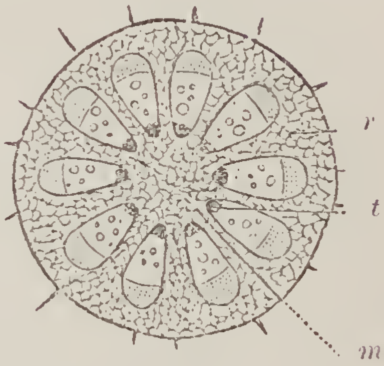

Fig. 58.

Fig. 57.—Transverse section of the stem of an oak six years old—*i.e.*, having six concentric woody circles; cellular pith in the centre, surrounded by spiral vessels, and woody layers consisting of woody tubes and porous vessels, layers of bark both cellular and fibrous on the outside.

Fig. 58.—Section of an Exogen, during its first year of growth; *m* cellular pith, very large and occupying a considerable part of the stem; *t* spiral vessels forming a layer round the pith; *r* large cellular rays joining the pith and bark, which is represented by cells on the circumference. The woody and porous vessels are placed between the pith and the bark, and are divided into ten wedges by the rays.

after year, the stem increasing in diameter by circles of wood on the outside of those previously formed. The new wood is on the outside, the old wood within. Such trees are hence called Outside-growers or *Exogens,* and they have their hard-wood in the inside, their soft wood on the outside.

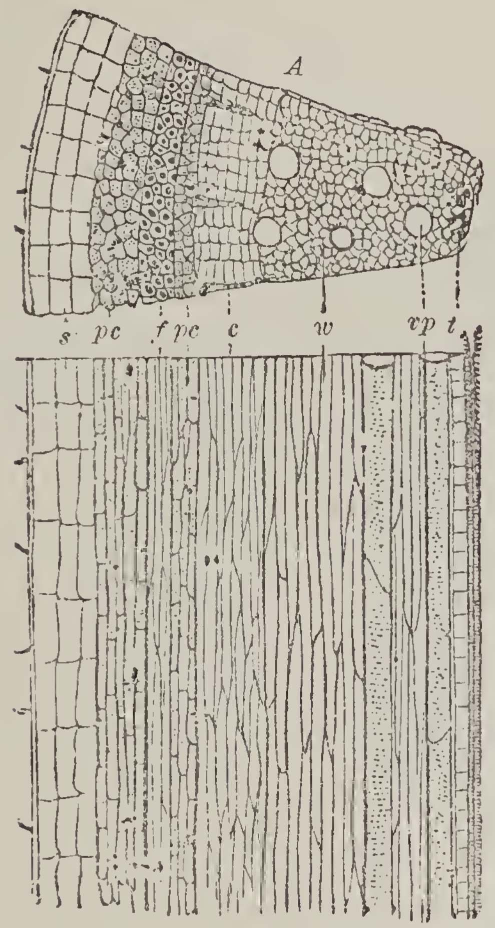

Fig. 59.

The structure of the different parts of such a stem is represented in fig. 59, where A is a transverse section, and B is a longitudinal one, of the stem of a maple one year old. In these figures, *t* indicates the spiral vessels (fig. 20, p. 28) round the cellular pith; *vp* are porous vessels (fig. 16, p. 28), showing large round aper-

Fig. 59.—Stem of a maple at the commencement of its second year of growth. A transverse or horizontal section; B longitudinal or perpendicular section; *t* spiral vessels round the pith; *vp* porous vessels with large apertures; *w* woody fibres; *c* layer of sap wood between bark and heart-wood; *pc*, *pc* inner cellular portion of bark separated by woody fibres of the bark *f*; *s* outer cellular corky layer of bark.

tures; *w* woody fibres (fig. 14, p. 27); *c* a layer of new wood or alburnum next to the bark, which is composed of cells *s* and *pc*, and of fibres *f*. A stem of maple, three years old, is given in fig. 60. Taking the woody part of the stem, we find that during the first year (1) there is the cellular pith *m*; spiral vessels *t*; porous or dotted vessels *v*; and woody fibres *f*. In the second year (2) there are seen dotted vessels *v*; and woody fibres *f*. So also in the third year (3). A layer of new wood below the bark is marked *c*. The outer bark, sometimes of a corky nature, as in the cork oak, is marked *s*; and below it are different layers of bark, composed

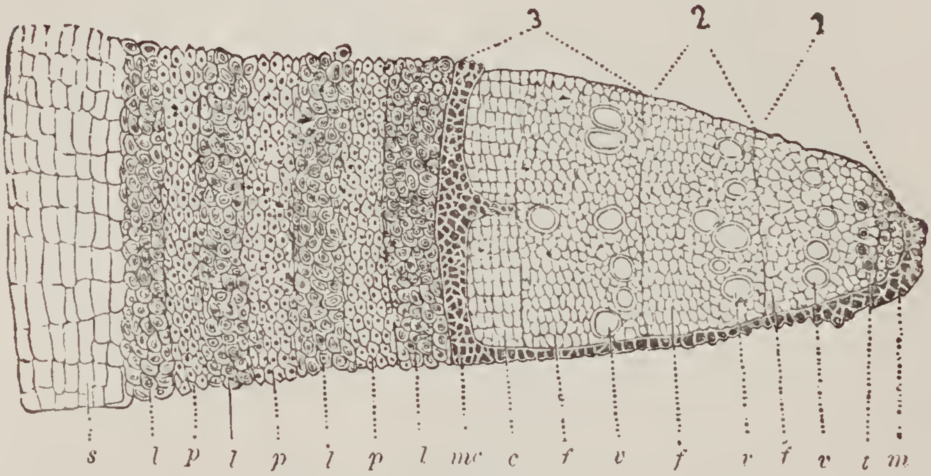

Fig. 60.

Fig 60.—Transverse section of a maple three years old—1, 2, 3, being the woody growth of each year, the layers of bark extending from *s* to *mc*. The pith is marked *m*; spiral fibres *t*; porous vessels *v*; woody fibres *f*; layer of new wood *c*; layer of new bark cells *mc*; inner woody fibres of bark *l*; cellular layer of bark *p*; outer corky bark *s*.

of woody fibres *l* and cells *p;* while next the newest wood *c*, there is a cellular layer connected with the bark, marked *mc.*

The woody tubes in cone-bearing trees, as fir, spruce, larch, cedar, cypress, and Araucaria, exhibit markings called discs, which appear in the form of a circle and a dot in the centre. Sometimes these discs are in single rows, as in fig. 61; in others they are in double or triple rows, as in figs. 62 and 63. When the rows are more than one, they are arranged in parallel series, the discs being either opposite to each other, as in Firs (fig. 62), or alternate with each other, as in Araucaria and Altingia (fig. 63). One of these latter plants, *Altingia excelsa,*

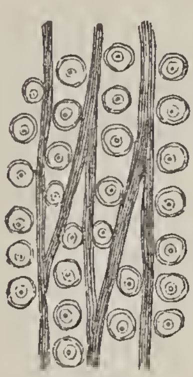
Fig. 61.

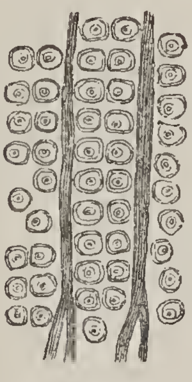
Fig. 62.

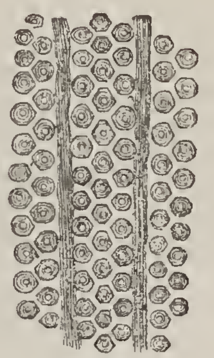
Fig. 63.

Figs. 61, 62, 63, were taken from specimens, kindly furnished by Mr Nichol who, was celebrated as having led the way in sections of fossil woods, and whose collection of microscopic sections of wood is unrivalled. Fig. 61, woody tubes of fir, with single rows of discs; fig. 62, woody tubes of fir, with double rows of discs, which are opposite to each other; fig. 26, woody tubes of *Altingia excelsa*, with double and triple rows of discs, which are alternate.

or Norfolk Island Pine, is represented in fig. 64, from a specimen grown in the Royal Botanic Garden, the wood-cut of which was kindly contributed by the late Hugh Miller. The plant is interesting, on account of the markings in its wood, as well as from the fact that plants allied to it are now found in Britain in a fossil state, for instance, at Craigleith and Granton quarries.

From the mode of growth in exogenous trees, it is obvious that we can ascertain the age of the tree by counting the number of woody circles. Thus, in fig. 57, p. 76, the oak is six years old. This calculation can be made with tolerable correctness in trees of temperate and cold climates, where during the winter there is a marked interruption to growth, and thus a line of demarcation is formed between the circles; but in trees of warm climates, this

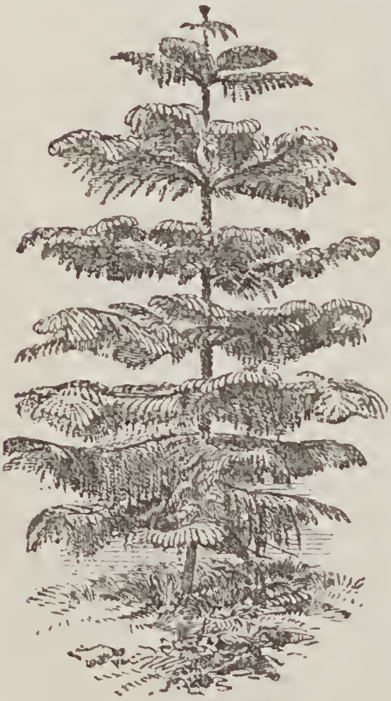

Fig. 64.

Fig. 64.—Specimen of *Altingia excelsa*, or Norfolk Island pine, in the Royal Botanic Garden of Edinburgh.

mode of estimating age may lead into error. It would appear that in these there are often the appearance of numerous circles in one year. The age of 5000 years or more, attributed to some Baobabs in Senegal, and to specimens of Wellingtonia in California, may be accounted for in this way. Even in the trees of this country, when they get old, it is found that the different circles are so blended as to make it difficult to count them accurately.

The wood in the centre of exogens is often altered in colour, by peculiar coloured woody matter being deposited in the tubes. Thus the heart-wood of the ebony tree is black, and that of the oak deep brown, while that of the outer soft wood is pale. The latter is the part in which the active processes of life go on; and hence, if it is destroyed, the plant dies. A woody plant, such as honeysuckle, or some Bauhinias of foreign countries, twining round the stems of such trees, cause strangulation, in consequence of the mode of their growth by external additions; and in process of time, if the woody climber is sufficiently strong, and does not break or yield, the vessels of the soft wood are impeded in their growth, and the tree will ultimately be destroyed. In fig. 65, A, a twining plant, called the *bush-rope* in the West Indies, is seen causing contractions of the stem. Sometimes grooved sticks are formed in the same way in Britain, by the wining of the honeysuckle round neighbouring trees. The size attained by the stems of many dicotyledons, both as regards height and diameter, is sometimes very great. Trees belonging to the cone-bearing tribe vary in height in general from 100 to 200 feet. The oak sometimes attains the height of 120 feet; and forest trees on the Continent and in America are met with 150 feet high. The celebrated mammoth pine of Oregon (*Wellingtonia gigantea*) is seen 320, and sometimes upwards of 400, feet high. Some cedars of Lebanon have a girth of 40 feet, chestnuts

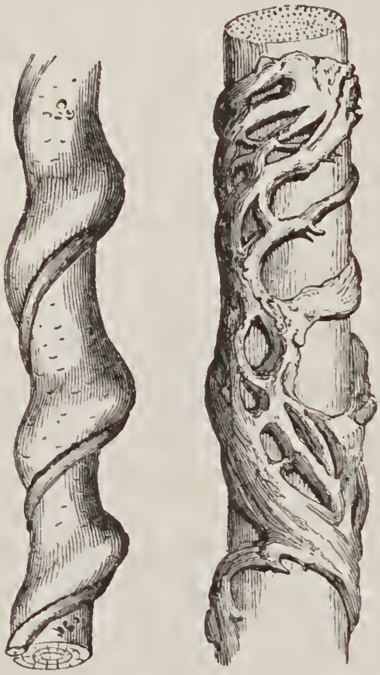

Fig. 65.

Fig. 65.—The effects of twining plants on different stems. A, the Bush-rope, a climbing-plant, twining round the stem of an Exogen, and causing strangulation; B, a Bauhinia, or woody-climber, twining round the stem of an Endogen (a palm), and not causing any strangulation. Specimens of both are seen in the Museum of the Botanic Garden, contributed by Dr W. Campbell, Demerara, and Mr Drummond of Stirling.

occasionally attain to 60 feet, and the baobab-tree of Senegal (*Adansonia digitata*) has been measured 90 feet, in circumference. A specimen of Wellingtonia (*Sequoia gigantea*) measured, at 5 feet from the ground, 20 feet 2 inches in diameter; at 18 feet, 14 feet 6 inches; at 100 feet, 14 feet; at 200 feet, 5 feet 5 inches. The bark of the tree was 12 to 15 inches thick. Dr Torrey has recently examined the stem of one of these trees, and has counted the number of circles in a complete radius. He finds that they are 1120. The first 100 circles occupy a breadth of 17½ inches; the second, 14; the third, 12½; the fourth, 13; the fifth, 16½; the sixth, 8¾; the seventh, 7¾; the eighth, 11; the ninth, 10; the tenth, 11; the eleventh, 11¼; the remaining twenty layers, 1. There are 1120 layers in a semi-diameter of 135 inches, or 11 feet 3 inches. In England, the following is the average growth of vigorous oaks:

	Inch. diam.	Years.
First 50 years,	12	50
Second ,,	19	100
Third ,,	26	150
Fourth ,,	32	200
Fifth ,,	36	250
Sixth ,,	40	300

In this computation it is assumed that after 100 years the rate of growth is reduced to 7 inches for the next 50 years; to 6 inches for the succeeding 50, and then falls permanently to an increase of 4 inches in diameter for every half century.*

Exogenous trees give a character to the landscape of the countries in which they abound. They have large trunks, which produce numerous branches, spreading in all directions. The trunk tapers as it ascends, and the branches become thinner towards their extremities. The mode in which the branches spread, and their comparative lengths, give rise to differences in the contour of exogenous trees. When the lower branches are largest, and they gradually diminish in length upwards, the trees are more or less pyramidal, as in the Douglas pine (*Abies Douglasii*); when the reverse takes place, they have an umbrella-like top, as in the Stone pine (*Pinus pinea*). M'Cosh says, "There is one glory of the oak, which looks as if it had faced a thousand storms, and having stood them all, were ready to face as many more; another glory of the sycamore, that spreads in gentle pomp its honeyed shade; another glory of the birch, so graceful in the midst of its maiden tresses; another glory of the elm, throwing out its wide arms, as if rejoicing in its strength; and another glory of the lime, with its sheltering shade, inviting us to enter and linger. Each has its own glory, of which it would be shorn were it to make an ambitious attempt to usurp the glory of its neighbour" (*Typical forms*, p. 107). The Cedar of Lebanon (fig. 66)—a tree often referred to in Scripture—will serve as an illustration of an exogen. In early times

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* Gardener's Chronicle, Nov. 6, 1858.

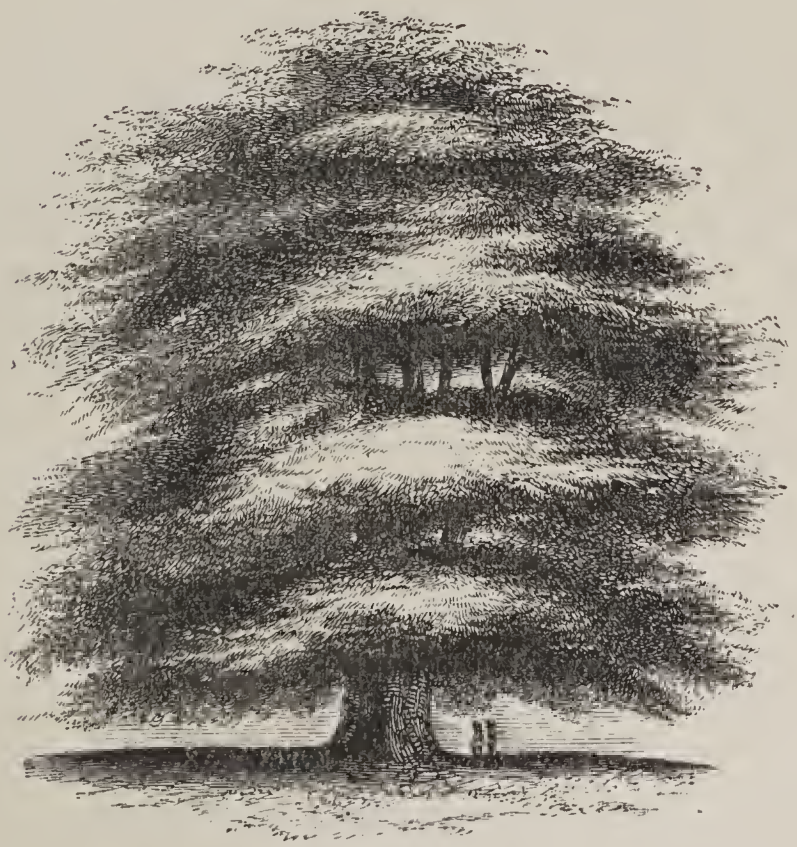

Fig. 66.

Fig. 66.—*Cedrus Libani*, the Cedar of Lebanon, an exogenous tree, with a thick trunk and spreading branches.

it appears to have grown abundantly in Lebanon, and to have formed its distinguishing feature. In later times there has been a great diminution in the number of cedars in Lebanon; so that, in 1832, there were only seven remaining, most of them apparently of a great age.* The cedar is a wide-spreading evergreen tree, from 50 to 80 feet high, with a large trunk, numerous large and long branches, which extend in a horizontal manner, nearly at right angles from the trunk, and with their evergreen leaves form a spacious shady covering. It is not liable to the attacks of climbing-plants. How beautifully does the prophet describe the character of the cedar, when he speaks of its high stature, its top among the thick boughs, its multiplied boughs, its long branches, and its shadowing shroud (Ezek. xxxi. 3-7). It was pre-eminently distinguished by its exalted growth. It is said in 1 Kings iv. 33, that Solomon "spake of trees, from the cedar-tree that is in Lebanon [as being the most conspicuous and noble], even unto the hyssop [or caper-bush] which springeth out of the wall." It is also spoken of as "the glory of Lebanon" (Isa. xxxv. 2; lx. 13);

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* Magnificent specimens of *Cedrus Libani* grow in Caramania far from those on Lebanon. Along with these cedars occur also *Abies cilicica* and *Juniperus drupacea.*—Gardener's Chronicle, June 17, 1854.

and the abundance of its fruit or cones is noticed in Ps. lxxii. 16. The strength and durability of the tree was a subject of common remark; and the Psalmist emphatically describes the power of the Lord when he says, "The voice of the Lord breaketh the cedars; yea, the Lord breaketh the cedars of Lebanon" (Ps. xxix. 5). In Ps. xcii. 12, the righteous man is represented as growing like a cedar in Lebanon. This seems to refer to his vigour, and to the outward active manifestation of spiritual life, which, like the spreading branches, are conspicuous to all, and show the beauty of holiness. In Numb. xxiv. 6, the people of God are likened by the wicked prophet to cedar-trees beside the waters; and in Ps. lxxx. 10, Israel is spoken of as sending out her boughs like the goodly cedars. How well do these figures picture the believer's growth in grace. He is like a goodly and excellent cedar (Song of Sol. v. 15), vigorous and evergreen, showing forth the power and glory of God, fixed in the Rock of Ages, whence are all his well-springs, which refresh and invigorate him even as a well of living waters and streams from Lebanon (Song of Sol. iv. 15).

Another marked type of stem occurs in some herbaceous plants, such as lilies and grasses, and is well seen in palms and certain trees of warm climates. In them the increase of growth is by additions of woody and porous vessels towards the centre. The stem is at first entirely cellular, but in the progress of growth, bundles of vessels are formed among the cells. These gradually increase and distend the stem to a certain amount the first year. Next year new bundles are produced inside the last, which increase the diameter still more, until at length by successive additions the stem is distended to the utmost. The outer portion becomes hard, so as sometimes to resist the blow of a hatchet, while the inner part is comparatively soft. This woody growth has given rise to the name of Inside-growers or *Endogens,* applied to plants having stems of this kind. On making a section of a palm stem, the appearance presented is seen in fig. 67. There is no distinct pith, no concentric circles, no rays, no separable bark. The outer part representing the bark is hard, and is incorporated with the woody fibres below. The interior consists of cells *m,* in which bundles of vessels *f,* are dispersed irregularly. In tracing the vessels *f v,* in the vertical section of a palm (fig. 68), it is found that they follow a curved course, and interlace with each other. Palms have straight trunks of nearly equal diameter throughout,

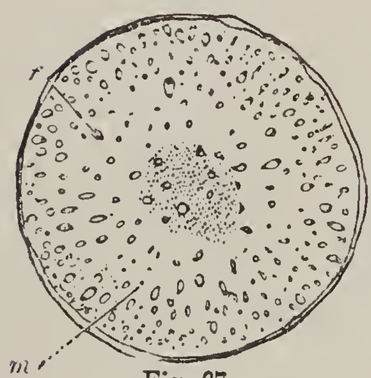


Fig. 67.

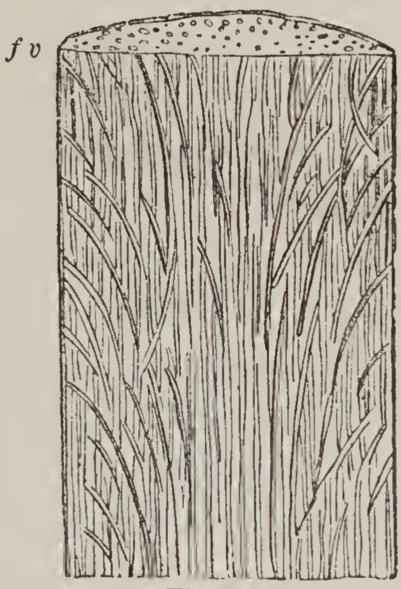


Fig. 68.

bearing a cluster of leaves at the summit. This character is seen in fig. 2, *a*, p. 9, and in fig. 69, p. 91. They rarely branch, and grow chiefly in height, not much in diameter. The age of a palm may be ascertained by measuring its height, for it is found that the growth in an upward direction is pretty nearly uniform in each species. From the small increase in diameter, and the hardness of the exterior, a

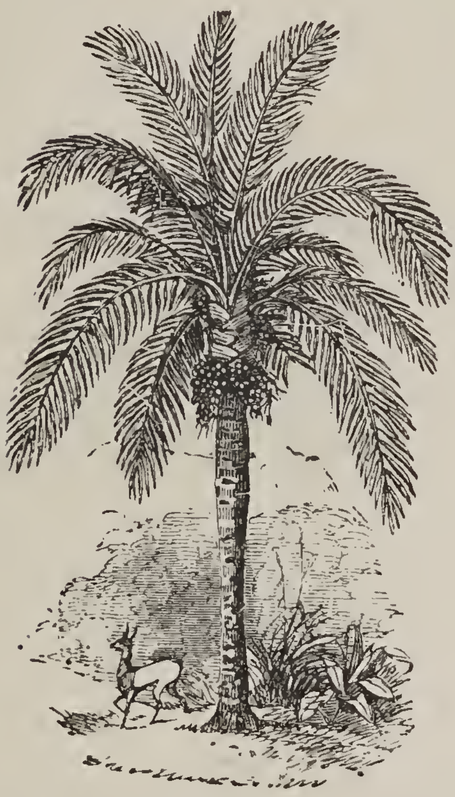
Fig. 67.—Transverse section of a palm stem, showing endogenous structure. Cellular tissue *m*; bundles of woody and other vessels *f*. No concentric circles, no rays.

Fig. 68.—Longitudinal section of a palm stem. Woody fibres *f v*, descending in an oblique manner, and interlacing.

twining woody plant does not injure a palm-stem. In fig. 65, B, p. 82, is seen a palm-stem with a woody bauhinia twisting round it, without affecting its growth. When the tuft of leaves at the summit of a palm is completely destroyed, the plant dies, because there is no provision for lateral buds, as in our trees. Williams the missionary relates, that in the South Sea Islands they destroy the coco-nut trees in this manner.

Palms give a marked and distinctive character to the vegetation of tropical regions, and their umbrageous foliage, particularly in the case of those with fan-shaped leaves, affords an excellent shelter from the sun's rays. In figs. 69, 70, 71, 72, and 73, are represented the wax palm of South America, the oil-giving palm of Guinea, the cabbage palm of the West Indies, the Talipot palm of the East Indies, and the date palm of Egypt. In all of these, we remark the erect growth, the bare unbranched stem of nearly uniform diameter throughout, and the crown of leaves at the summit, from which the flowering stems and fruit proceed.

Many palms yield edible fruits, containing a great quantity of oil or fatty matter. Humboldt says that they yield wine, oil, wax, flour, sugar, thread, utensils, weapons, food, and habitations. The date palm (fig. 73) is that referred to in the Bible. The coco-nut palm (fig. 2, *a*, p. 9) is put to many important uses; its root is chewed, the fibrous matter surrounding its leaves is used for cloth and for sails; its stem is employed for building and making spears, the wood is imported under the name of porcupine wood; its leaf-bud is


Fig, 69.

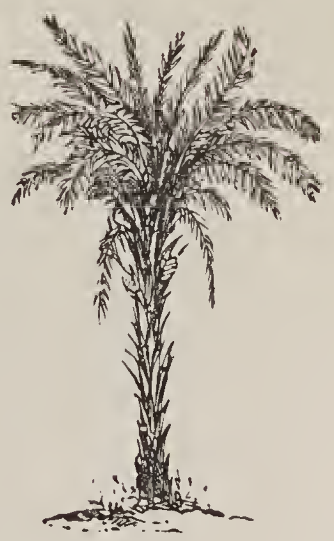


Fig. 70.

Fig. 69.—*Ceroxylon Andicola*, the Wax palm of the Andes. Its trunk furnishes a waxy secretion.

Fig. 70.—*Elais Guineensis*, the palm from the fruit of which solid palm oil is procured.

used as an article of food like cabbage; its leaves are used to thatch houses, to make baskets, lanterns, carpets, bonnets, paper; the midrib of the leaf is used for oars and paddles, the husk of the fruit is used for cordage, the hard shell for cups and basins, the kernel for food and for giving oil; and the flower-stalk yields a sweet juice which is fermented.

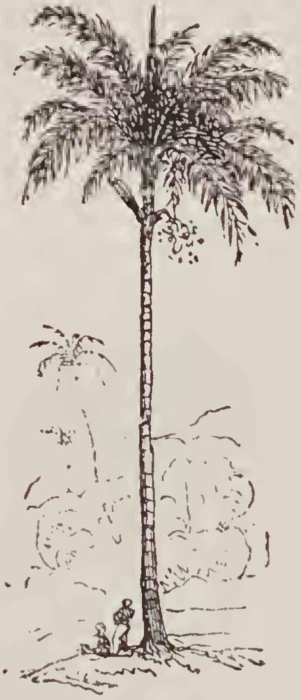


Fig. 71.

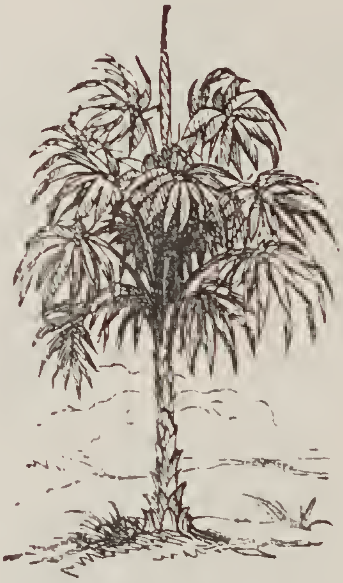


Fig. 72.

Fig. 71.—*Areca oleracea*, Cabbage palm. The flowering stalk is used as food, and so is the young bud.

Fig 72.—*Corypha umbraculifera*, the Talipot palm. It has large fan-shaped leaves.

"Sometimes Thou dost divide thy gifts to man,
Sometimes unite. The Indian nut alone
Is clothing, meat and trencher, drink and cann,
Boat, cable, sail, and needle, all in one."
G. Herbert.—*Providence.*

Kidder and Fletcher, in their history of "Brazil and the Brazilians," make the following remarks:

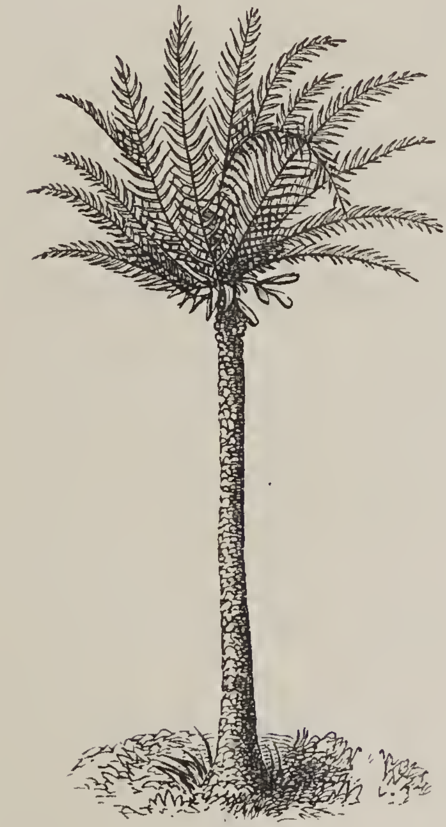


Fig. 73.

"The most generous gift which God has given to Brazil is the palm trees. These princes of the vegetable kingdom are extensively applied to the wants of man in the interior provinces and upon the sea coast. Palms furnish to the Amazonian Indians houses, raiment, food, drink, salt, fishing-tackle, hunting implements, musical instruments, and almost every necessary of life except flesh. Take the hut of an Uaupé Indian on one of the affluents

Fig. 73.—*Phœnix dactylifera,* the Date palm, the Tamar of Scripture (Exod. xv. 27; Ps. xcii. 12).

of the Rio Negro. The rafters are formed by the straight and uniform palm called *Leopoldinia pulchra;* the roof is composed of the leaves of *Mauritia carana;* the doors and the framework of the split stems of the *Iriartea exorhiza* or Paxiuba palm. The matting or mattulla of another species is sometimes used as an apron. The Indian's hammock, his bow-strings, and his fishing-lines, are woven and twisted from the fibres of different palms. The comb with which the males of some of the tribes adorn their heads is made from the hard wood of a palm; and the fish-hooks are made from the spines of another. The Indian makes from the fibrous spathes of the *Manicaria saccifera* caps for his head, or cloth in which he wraps his most treasured feather ornaments. From eight species he can obtain intoxicating liquor; from many more he receives oil, and a harvest of fruit; and from the *Leopoldinia major* he procures, by burning the large clusters of small nuts, a substitute for salt. From another he forms a cylinder for squeezing the mandioca-pulp. The large woody spathes of *Maximiliana regia* are used by hunters to cook meat in, and they are also employed as cradles, and for carrying earth. Arrows are made from the spinous processes of the *Œnocarpus Batana* or

Patanà, and lances and heavy harpoons from the *Iriartea ventricosa.* The long blowpipe or gravatáua, through which the Indian sends the poisoned arrow, that brings down the bright birds, the fearless peccari, and even the thick-skinned tapir, is furnished by the *Iriartea setigera* palm. The great bassoon-like musical instruments, used in the devil-worship of the Uaupés, are made from the stems of palm trees."

The Indians write on ollas or palm leaves. They are dried in the sun, and written upon with an iron style or pen. Over the characters thus made lamp-black is rubbed. The leaflets are long and narrowish, with the bottom and top cut off. They are strung together with a ribbon, after being written on, two round holes being stamped in each leaf; thus a book is made.

In Ps. xcii. 12, the Psalmist says, that "the righteous shall flourish like the palm-tree." To those who inhabited Palestine, the illustration would lead them to contemplate the straight and erect growth of the tree, its unbranched and unencumbered stem, and the beauteous crown of leaves at its summit. It would also recall to their minds that the palm flourished in the desert, and that its presence there always indicated moisture, which enabled it to grow amidst surrounding barrenness. In Exod. xv. 27, it is said that the children of Israel "came to Elim, where were twelve wells of water, and threescore and ten palm-trees." The believer's growth, like that of the palm, is internal, and unseen by the world.* His age is determined by his nearness to heaven. His stature, as Solomon says, is like the palm-tree (Cant. vii. 7), and he grows up to the measure of the stature of the fulness of Christ (Eph. iv. 13). He grows in a bleak and barren wilderness, but he has sources of joy and of refreshing which the world knows not. The allurements of the world twine round him, and he is surrounded by trials and temptations, but they do not impede his growth. He towers above all, pointing heavenward. Linnæus called the palms the princes of the vegetable kingdom. So the believer, as a prince, has power with God, and prevails through his living Head (Gen. xxxii. 28). The palm, which used to be a frequent tree in Palestine, is now said to be rare. Like the righteous, it has been rooted out, and is, as it were, a small remnant in a land where once it flourished in beauty and vigour. The clusters of fruit which palms produce when old, and the fatty oils which they supply, may be referred to in the statement that the righteous "shall still bring forth fruit in old age; they shall be fat and flourishing" (Ps. xcii. 14).

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* While the endogenous palm represents faith and inner growth, the exogenous cedar represents work and outward beauty.

Another conspicuous permanent stem is that which occurs in ferns, especially in the tree-ferns of New Zealand, and of tropical countries (fig. 74). In these plants the stem is uniform in its diameter, hollow, and marked on the outside by the scars of the leaves (fig. 75, *c*). The stem increases by additions to the summit, and hence the plants are called Summit-growers or *Acrogens.* The stem is, in fact, formed of the bases of the leaves, which carry up the growing point with them, and the elegant clusters of feathery leaves hang from the top. On making a transverse section of such a stem, the appearances seen are represented in fig. 76, where *e* is the outer portion, marked by the scars of fallen leaves, *fv* bundles of vessels of an irregular form, dark outside, pale in the centre, *p* outer layer of cellular tissue, *m* central cells, which are usually absorbed so as to leave a cavity. In the common brake or brackens of our pasture, the lower part of the stem, when cut, exhibits bundles of vessels which have the form of an oak or of a double spread-eagle. Ferns characterise mild and moist climates, and they give a peculiar feature to the landscape of New Zealand. At former epochs of the earth's history, they appear to have constituted a large part of its vegetation.

We have thus seen the structure of the three marked forms of permanent woody stems which are met with in the vegetable world:—1. Exogenous or Outside-growers, consisting of pith, con-

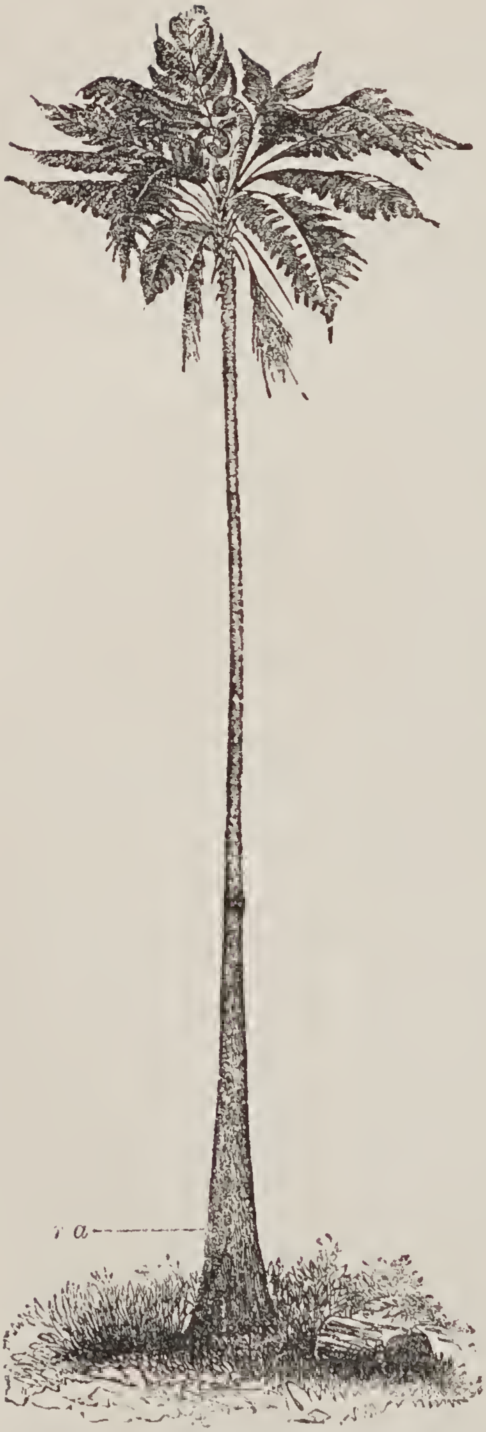

Fig. 74.

Fig. 74.—East Indian Tree-Fern (*Alsophila perrotetiana*). It has an

centric circles of wood, which increase by additions on the outside, separable bark, and rays connecting pith and bark; exemplified in the forest trees of Britain. 2. Endogenous or Inside-growers, consisting of a mass of cellular tissue with bundles of woody and other vessels scattered irregularly through the tissue, increasing by additions inside; exemplified in palms. 3. Acrogenous or Summit-growers, formed by the bases of the leaves

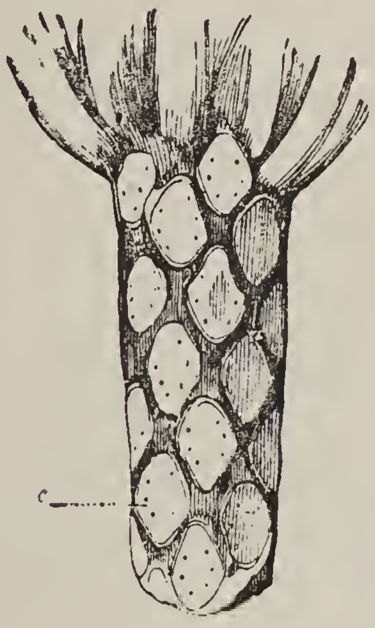

Fig. 75.

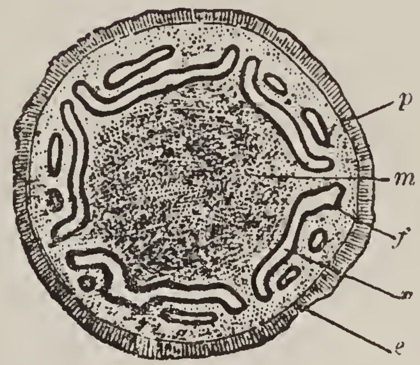

Fig. 76.

acrogenous stem, and its embryo is acotyledonous. The stem or stipe is unbranched. Towards the base *r a* there is an obvious enlargement caused by a number of adventitious or aerial roots which cover the stem, and are applied closely to it.

Fig. 75.—Stem of a tree-fern. It is acrogenous or increases at the top. The stem is uniform in diameter, marked by scars of fallen leaves *c.*

Fig. 76.—Transverse section of the stem of a tree-fern, showing the cellular portions *p m*, the irregular bundles of vessels *f v*, and the outer portions, *e*.

which carry up the growing point, additions being always made to the summit, bundles of vessels irregular; exemplified in tree-ferns.

We have already observed that the plants of the globe may be divided into three great classes by the nature of their embryo, viz.,—into Dicotyledonous, having two seed-lobes; Monocotyledonous, having one; and Acotyledonous, having none. These divisions correspond to those founded on the structure and development of the stem. Thus dicotyledons have exogenous stems, monocotyledons have endogenous stems, and acotyledons have acrogenous stems. Here we see a natural division of the flora of the world, and we perceive part of that plan which it has pleased the Creator to adopt in the formation of the plants with which He has clothed the globe. Uniting plants by affinities, such as those now stated, is following what is called a natural system in botany. By associating plants which agree in all essential points—as, for instance, in the structure of their seeds, stems, leaves, and flowers—we follow a more useful and philosophical method, than by taking into account only one or two parts of the plant, as was done by Linnæus and the advocates of an artificial arrangement.

The use of the stem is to support the leaves and flowers, and to expose them to air and light. The general form of stems is fitted to secure stability, and it is said that the bole of an oak suggested to Mr Smeaton the form best suited for the construction of the Eddystone Lighthouse. The sap circulates in the vessels and cells of the stem as well as in the spaces between them. In its upward course, it passes chiefly through the internal parts, being moved onwards by the force of imbibition and by capillary attraction, as modified by vital actions. When it has reached the leaves and has undergone certain changes, it returns towards the bark in its downward course. This course is indicated in fig. 77. The sap enters by the cells of the roots *a a*, ascends through the central parts of the stem *b b*, reaches the leaves *c c*, and returns by the bark *d d*. The arrows are placed to point out this course. The force with which the sap ascends is very great. It was measured by Hales, by means of an instrument represented in fig. 78, where *a* is the trunk of a tree such as the vine, *f g e d* is a bent glass tube containing mercury, which stands at the level *e f*; *b* is the extremity of the tube, which is fastened to the trunk by means of a bladder *c*, firmly tied round. The sap, when flowing freely, forced the mercury to the point *g*.

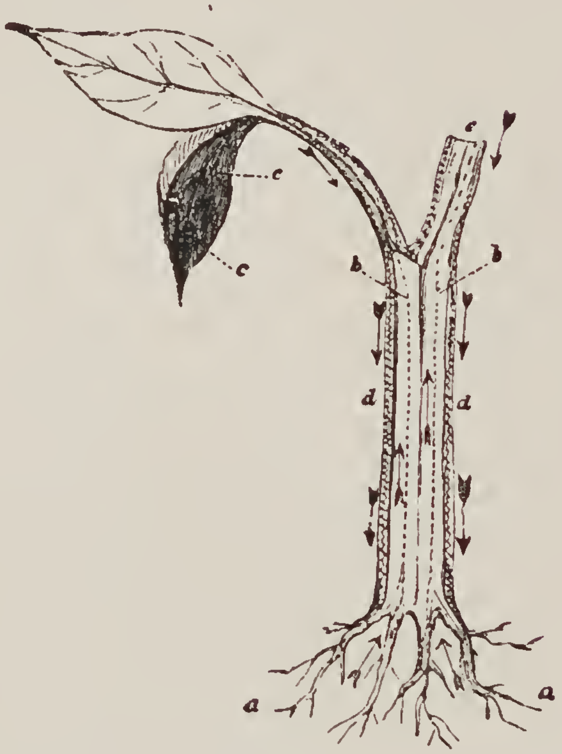

Fig. 77.

There is also observed in plants a peculiar force called osmotic, by means of which fluids pass from one cell to another through the membrane forming their walls. The following remarks on osmotic power are made by Professor Graham:—" This power is that by which liquids are impelled through moist membranes and other porous septa, in experiments of

Fig. 77.—Figure intended to represent generally, the upward and downward course of the sap. *a a* the roots, *b b* vessels, cells, and intercellular canals of the stem, *c c* leaf-stalk and leaves, *d d* bark, *e* section of a branch. The direction of the arrows shows the course of the sap.

endosmose and exosmose. When there is a solution of salt on one side of the porous septum, and pure water on the other side, the passage of salt outwards is entirely by diffusion; the movement being confined to the liquid salt particles, and not influencing the water holding them in solution, which is entirely passive. The flow of water inwards effects sensible masses of fluid, and is a current. It is osmose. In diffusion the water introduced has always a definite relation to the quantity of salt which escapes. But not so in osmose. Capillarity will not account for osmose. The force seems to be connected with chemical action. Much depends on the septum. The septum constantly undergoes decomposition, and its osmotic action is exhaustible. The action on the two sides of the septum or

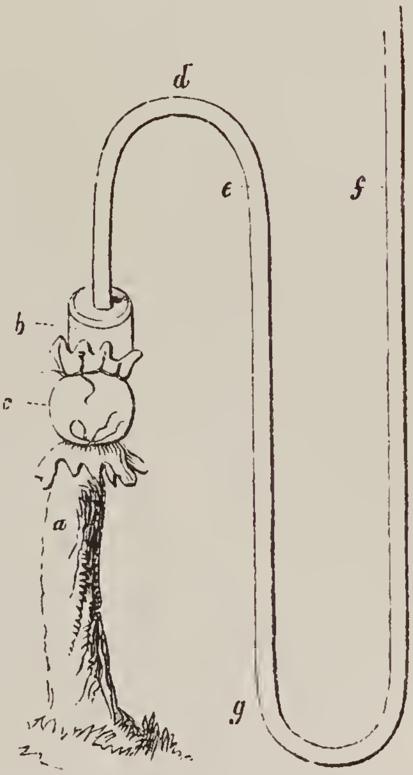

Fig. 78.

Fig. 78.—Instrument used by Hales to show the force of the sap, consisting of a bent tube *f g e d*, attached to the trunk of a vine *a*, by a large extremity *b*, and a bladder *c*.

membrane is unequal in degree and different in kind. In the case of a salt there appears to be an alkaline action on the inner surface of the membrane and an acid action on the outer. The water appears to accumulate on the alkaline or basic side of the membrane. With an alkaline salt, as carbonate or phosphate of soda, in the osmometer and water outside, the flow is inwards. With an acid in the osmometer, on the contrary, the flow is outwards, or there is negative osmose, the liquid then falling in the tube. In the last case, the water outside is basic, when compared with the acid within, and the flow is therefore still towards the base. Salts which admit of dividing into a basic subsalt and free acid, exhibit much osmotic activity, such as acetate of alumina, iron and chromium, protochloride of copper and tin, chloride of copper, nitrate of lead, etc. The chloride of sodium, of barium, of magnesium, and similar neutral salts, are wholly indifferent, or appear only to act in a subordinate manner to some more active acid or basic substance, which last may be present in the solution or membrane only in the most minute quantity. The bibasic salts of potash or soda, such as sulphate or tartrate of potash (although strictly neutral in properties), begin to exhibit a positive osmose, in consequence probably of their possible resolution into an acid supersalt and free alkaline base. A chemical character is thus assigned to osmose, accompanied with a constant decomposition of membrane. In the living state a renewal of the membrane is constantly taking place. Osmose is peculiarly excited by dilute saline solutions. By osmose chemical affinity is converted, as it were, into mechanical power. In order to make experiments on osmose, Graham used cotton calico, impregnated with liquid albumen, and afterwards exposed to heat so as to coagulate that substance. This formed an excellent septum in the case of saline solutions, and resembling a membrane in every respect." *

The force of imbibition, or endosmose, has been shown by the instrument represented in fig. 79. This instrument is called a measurer of imbibition, or an endosmometer. It consists of a bent glass tube with a large bell-like extremity, full of syrup, covered with a bladder which may represent a vegetable membrane, and plunged into a jar of water. The syrup is introduced by the opening at the curvature of the tube *c*, which is secured by a plug firmly held down. Mercury is put into the tube *a*, so as to fill the lower curvature *d* up to a certain point, as represented by the dark lines. Syrup occupies the space between the mercury and the bladder. After the apparatus has been in the water for some time, the mercury begins to rise in the limb *a*, by the pressure behind, caused by the rapid imbibition of water, and the force can be estimated by having a graduated scale connected with the tube. When the syrup is dense, it is found that the imbibition is very powerful, and may amount to the force of three or four atmospheres—that is, it may equal 45 or 60 pounds, or even more, on the square inch of surface. Similar phenomena take place in plants through the membranes covering their cells and vessels,

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* Proc. Royal Soc., vol. vii., p. 88.

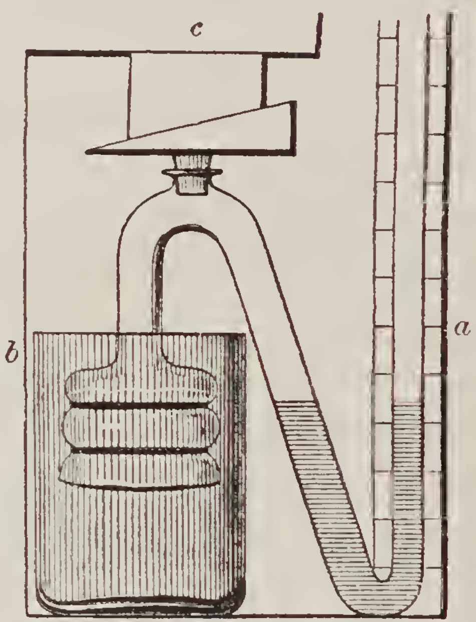

Fig. 79.

Fig. 79.—Endosmometer of Dutrochet, or measurer of the force of imbibition or endosmose. It consists of a bent tube *a*, with a graduated scale attached. Its extremity *b*, large, covered at the open end with a bladder or membrane of any kind. Syrup is poured into the large extremity through the opening *c*, which is closed firmly by a plug afterwards, and then it is put into a vessel of water. The effect on the mercury at the curve *d* shows the force.

which may be compared to the bladder in the figure. By means of this force, in part, as well as capillary attraction, the movement of the sap takes place. This, however, will not account for it entirely, and we must look to other causes besides those of a physical nature in determining the movements of fluids in living bodies. We shall find that the process of exhalation, or giving out of fluid from the leaves, materially assists these agencies ; and in the case of laticiferous vessels, the conspicuous movements of the sap in them appear to be influenced by some vital powers not yet determined. In fig. 80 is given a drawing of these vessels in the celandine, with arrows indicating the course of the fluids. The movement requires a good microscope in order that it may be seen, and also demands careful management so as to avoid all source of fallacy. The peculiar sheath or bract which covers the leaves of the Indian rubber fig in its young state is one of the best objects for showing this circulation, which ought to be looked for when the plant is growing, and in circumstances in which no injury is inflicted.

Various are the uses to which the woody stems of trees are applied. The heart-wood of exogens is more durable than the outer or sap-wood, and is less liable to attacks from dry-rot which is caused by the growth of a peculiar kind of mould. The outer bark often becomes very thick, and in the cork oak, it supplies the important substance called cork. The inner bark is fibrous, and is used to furnish ropes and mats. What are called Russian mats are procured from the inner bark (the *bast*) of the

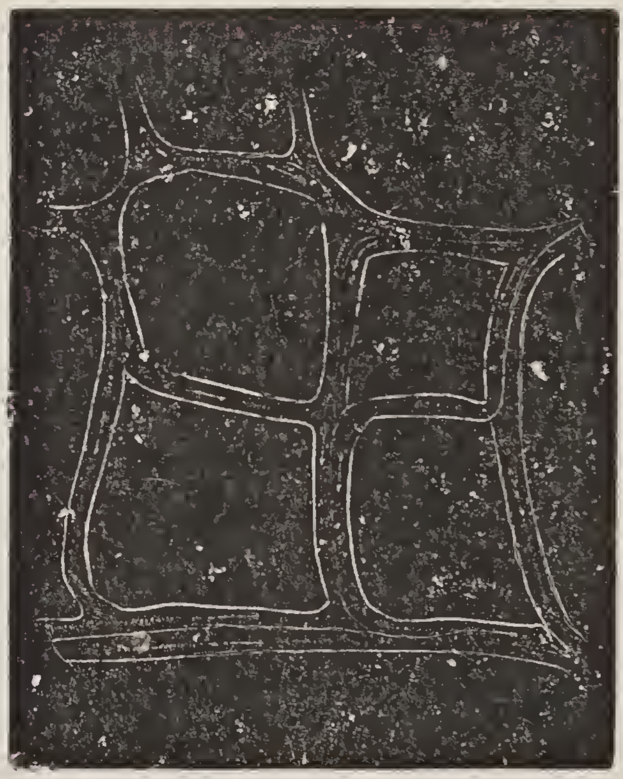

Fig. 80.

Fig. 80.—Portion of the leaf of Celandine, showing the laticiferous vessels in which movements of fluids take place, as indicated by the arrows.

lime tree. Cuba bast is got from the bark of *Hibiscus tiliaceus.* The inner bark of the lace-bark tree exhibits beautiful meshes like lace. Hemp and flax are the produce of the part of the plants which corresponds to the bark. A kind of hemp in India is procured from the inner bark of a species of *Hibiscus.* Many of the nettle tribe also yield useful fibres from the bark. The grass tree of China (*Boehmeria nivea*), which yields fibres used in manufacture, belongs to this tribe. The common hollyhock and other plants of the Mallow tribe are also used for supplying fibres. The inner bark of trees is also used in some countries for manuscripts, and hence the name of liber or book applied to it.

VI.—ON THE NATURE OF BRANCHES.

These are produced in the form of buds which are connected with the centre of the woody stem. They occur especially in exogens, and they have the same structure as the stem from which they proceed. Branch-buds are arranged on the stem in a regular manner, and follow the same law of spiral symmetry as will be noticed in the case of the leaves. But, owing to various causes, it is rare to find all the buds properly developed.

Many lie dormant, and do not make their appearance as branches unless some injury has been done to the plant; others are altered into thorns; others, after increasing to a certain extent, die and leave knots in the stem. That thorns are, in reality, undeveloped branches, is shown by the fact that they are connected with the centre of the stem, that they bear leaves in certain circumstances, and that under cultivation they often become true branches. Many plants are thorny in their wild state, which are not so under cultivation, owing to this transformation. Thorns, as of the Hawthorn, differ totally from prickles, such as occur in the rose. The latter are merely connected with the surface of the plant, and are considered as an altered condition of the hairs, which become hardened in their structure.

In the curse which God pronounced on the soil when man fell, He said, "Cursed is the ground for thy sake; in sorrow shalt thou eat of it all the days of thy life. Thorns also and thistles shall it bring forth to thee" (Gen. iii. 17, 18). May we not see, in the production of injurious thorns, an arrestment by the fiat of the Almighty in the formation of branches, and thus a blight passed on this part of creation, a standing memorial of the effects of sin on what was declared at first to be very good? The same remark may be made in regard to prickles, which are well seen in the briar and bramble, and which may be considered as an alteration in the development of hairs, a change on them which is associated with injury to man. We often find thorns, briars, and brambles alluded to in the Sacred Writings, as indications of the wrath of God against a backsliding and rebellious people. In Heb. vi. 8, St Paul says, "That which beareth thorns and briars is rejected, and is nigh unto cursing; whose end is to be burned." In proclaiming the judgments of the Lord, Isaiah says, "There shall come up briars and thorns" (v. 6). "All the land shall become briars and thorns" (vii. 24). "Thorns shall come up in her palaces, nettles and brambles in the fortresses thereof" (xxxiv. 13). So also Hosea says, "Thorns shall be in their tabernacles" (ix. 6); and "The thorn and the thistle shall come up on their altars" (x. 8).

Travellers in Palestine have particularly remarked the abundance of prickly and thorny plants in the land. Mr Dautrey, in his work entitled, "The Bible in Palestine," states, "That the plain near Tiberias is in many places a complete wilderness of thorns and thistles. They render some of the hills impassable, and entangle the foot of the traveller on spots formerly rich in culture." In many parts of Syria, cactuses form impenetrable barriers on account of their prickles. In the narrative of the Church of Scotland Deputation to Palestine, it is stated:—"Dr Keith, observing one of the adjoining hills to be very verdant and not very steep, set out for the purpose of climbing it. After a short absence, however, he returned to tell us that he had failed in his attempt. He found the surface overgrown with strong briars and thorns, through which he tried to make his way, but without success." How complete the fulfilment of the prophecy, "They shall lament for the teats, for the pleasant fields, for the fruitful vine. Upon the land of my people shall come up thorns and briars" (Isa. xxxii. 12, 13).*

Krapf, in his account of his travelling in south-eastern Africa (on the way to Usambara), mentions that the road was sometimes obstructed by the euphorbia and wild aloe. The pricks of these plants were very severe, and caused great pain. Dr Cleghorn remarks, —"The great prevalence of prickly shrubs all over India is observed by every one; they are a continual source of annoyance to the traveller, and a fruitful cause of admission into hospitals, as every regimental surgeon can testify. The prickles and spines of these plants wound the barefooted pilgrim, especially during the hot months, when the leaves having dropped off, the thorns are left bare and exposed; on this account travelling is rendered extremely difficult in some parts, for the spines are so strong as to pierce a shoe or sandal of dressed leather; and, if the weary traveller seeks to rest himself, he must beware as much of thorns as of red ants, tarantulæ, and other biting insects which infest the soil." *

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* Some of these thorny plants of Palestine are *Zizyphus Spina-Christi*, *Zizyphus Paliurus*, *Tribulus terrestris*, *Ononis spinosa*. See Kitto's Biblical Cyclopædia, article "Thorns and Thistles."

It is remarkable to notice that when Christ became a curse for His people, the Jews mocked Him by putting on Him a crown of thorns; and thus, what was an indication of the fall of man, was used by them to insult the seed of the woman who came to bruise the head of the serpent. The removal of the curse from creation, which is now groaning and travailing

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* For a full account of the thorny Indian plants, see Dr Cleghorn's paper on the Hedge Plants of India, in the Annals of Natural History, second series, vol. v., p. 233.

in pain (Rom. viii. 22), is frequently set forth by illustrations taken from the disappearance of briers and thorns. Thus, in Isa. lv. 13, it is said,—"Instead of the thorn shall come up the fir tree, and instead of the brier shall come up the myrtle tree: and it shall be to the Lord for a name, for an everlasting sign that shall not be cut off." Ezekiel says,—"There shall be no more a pricking brier unto the house of Israel, nor any grieving thorn of all that are round about them, that despised them; and they shall know that I am the Lord God" (xxviii. 24). "In that day shall the Branch of the Lord be beautiful and glorious, and the fruit of the earth shall be excellent and comely for them that are escaped of Israel" (Isa. iv. 2). When He who is the Branch out of the root of Jesse (Isa. xi. 1) shall take to Himself the kingdom, there shall be nothing to hurt nor destroy in all God's holy mountain: for the earth shall be full of the knowledge of the Lord, as the waters cover the sea (Isa. xi. 9, and lxv. 25). Then shall the "Spirit be poured upon us from on high, and the wilderness shall be a fruitful field, and the fruitful field be counted for a forest. Then judgment shall dwell in the wilderness, and righteousness remain in the fruitful field. And the work of righteousness shall be peace; and the effect of righteousness, quietness and assurance for ever" (Isa. xxxii. 15-17).

VII.—ON THE STRUCTURE, ARRANGEMENT, AND FUNCTIONS OF LEAVES.

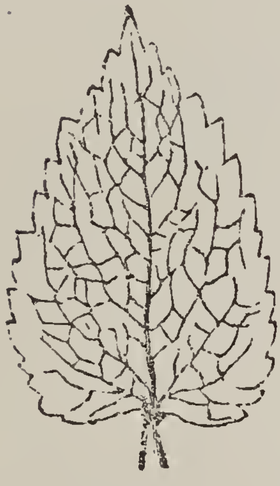

Fig. 81.

The structure of leaves exhibits a beautiful arrangement of cells and vessels, as seen in fig. 81, where the dark lines indicate the vessels or veins of the leaf, and the intermediate spaces the cellular parts of it. On making a section of a leaf from the upper to the under surface, and examining it under the microscope, we see the texture more clearly. This is delineated in fig. 82. The upper skin or epidermis of the leaf is marked *a*, the lower *g*, and between these are the cells and vessels. The cells at the upper side *b* are placed close together, with occasional air cavities *c*. Those of the lower side *f* are more loose, and have nume-

Fig. 81.—Reticulated leaf of the white dead-nettle (*Lamium album*) showing the distribution of the veins, or what is called venation.

rous air spaces *d.* The bundles of vessels forming the veins are marked *e,* while *h* shows hairs projecting from the surface, and *i* an opening or stomate through the skin into the cavity below. When leaves are left for a long time to macerate in water, the cellular part is destroyed, and the veins or vascular parts are left, forming the skeleton. How often have we seen leaves which have lain in ditches during the winter exhibiting a beautiful network of veins. In India and China, skeleton leaves are made from the leaf of a kind of fig

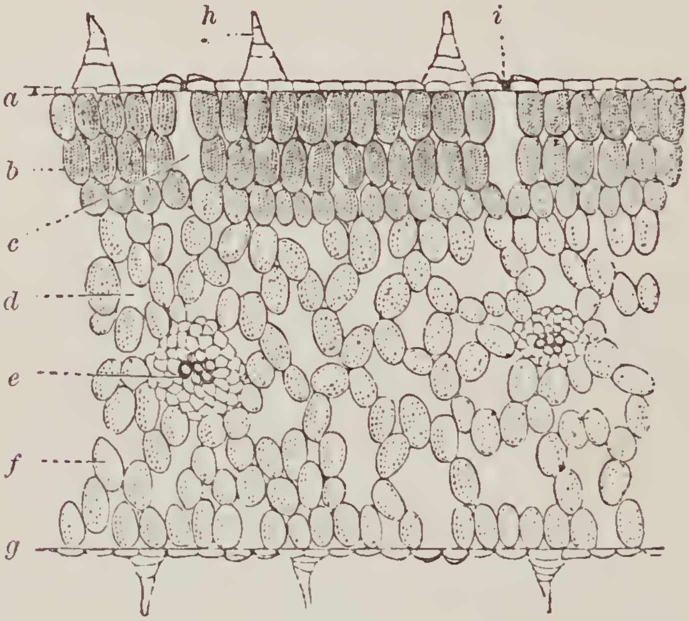

Fig. 82.

Fig. 82.—Section of the leaf of a melon, perpendicularly to its surface; *a* upper epidermis or skin; *g* lower epidermis or skin; *b* cells of upper part of leaf; *f* cells of lower part of leaf; *e* bundles of vessels; *d* air cavities; *c* cavity below a stomate; *i* a stomate; *h* a hair.

(*Ficus religiosa*). Skeleton leaves may be prepared by long maceration in rain-water, for as much as six or eight weeks, or more, in a warm place, freely exposed to the air. When nearly ready, carefully add a small quantity of muriatic acid, and finally pick out with care, by means of a needle, the cellular parts not rotted away. The whole may be bleached with chloride of lime, or simple chlorine, or the fumes of sulphur. How interesting, it has been remarked, is the anatomy of a single leaf, which, though so fragile as to tremble in every wind, yet holds connections and living communications with the earth, the air, the clouds, and the distant sun, and through these sympathies with the universe itself!

As regards the distribution of veins in leaves, flowering plants may be divided into two great classes: one having reticulated leaves, or exhibiting an angular net-work of vessels, as in fig. 83, which represents the leaves of the ordinary trees of this country; the other having no proper net-work, but a set of parallel or diverging veins running from the base to the extremity, as in grasses, lilies (fig. 85), and palms (fig. 84), or from the midrib to the margin, as in Bananas (fig. 23, p. 32), and Indian-shot. The first kind of leaf occurs in dicotyledons or exogens, the second in monocotyledons or endogens. This constitutes another means of discrimination between these two great classes of plants, and is one which can be easily detected by the student of nature.

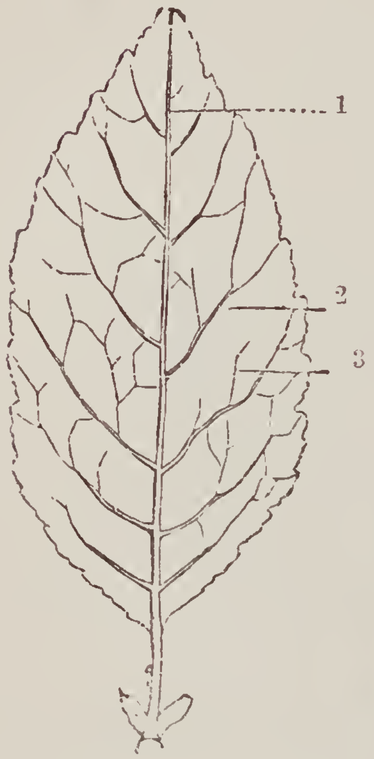

Fig. 83.

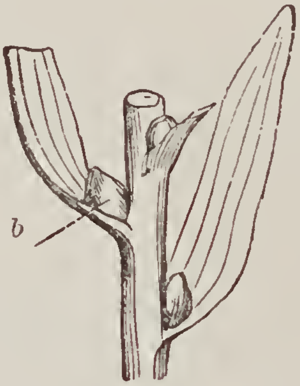

Fig. 85.

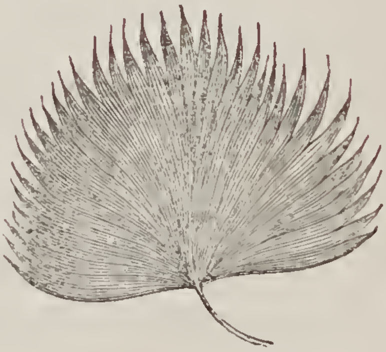

Fig. 84.

Sometimes the veins of leaves become hard-

Fig. 83.—Leaf of cherry, showing distribution of veins. 1 midrib; 2 primary veins, given off from the midrib; 3 secondary veins.

Fig. 84.—Palm leaf, showing parallel venation, the veins not being reticulated.

Fig. 85.—Stem of bulbiferous Lily (*Lilium bulbiferum*), showing bulbels or bulblets *b*, produced in the axils of the leaves, which exhibit parallel venation.

ened at their extremity, and project in the form of thorns, as seen in the holly (fig. 86) and the barberry. The same remark may be made in regard to them as has been applied to other thorns. They are produced by an arrestment in the development of the cellular part of the leaf, and a change in the structure of the veins. In the holly, we see that in certain circumstances it produces spineless leaves, in consequence of the cellular tissue filling up the spaces between the veins, even to the very edge. Southey has alluded to this in the following lines, but he has certainly given reins to his imagination in attempting to give a reason for the difference in the two kinds of holly leaves :—

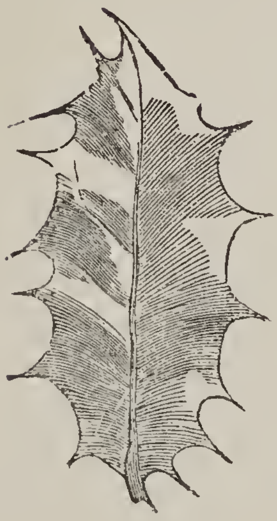

Fig. 86.

"O reader! hast thou ever stood to see
The Holly-tree?
The eye that contemplates it well, perceives
Its glossy leaves,
Ordered by an Intelligence so wise
As might confound the Atheist's sophistries.

Fig. 86.—Spiny leaf of Holly (*Ilex Aquifolium*). The spines are formed by the hardened extremities of the veins proceeding from the midrib to the margin.

"Below a circling fence its leaves are seen
Wrinkled and keen;
No grazing cattle thro' their prickly round
Can reach to wound;
But as they grow where nothing is to fear,
Smooth and unarmed the pointless leaves appear."

The surface of leaves presents certain pores or openings called stomata (fig. 87, *s t;* and fig. 82, p. 116, *i*). The cells surrounding these pores are so constructed that in dry weather they collapse, and close the opening; while in moist weather they have a crescentic margin, by which they open the orifice. They are connected with the passage of air and fluids to and from the leaf. In fig. 87 they are seen scattered over the surface at regular intervals. They are easily observed by putting a very thin piece of the skin of the leaf of a hyacinth or lily under the microscope. They

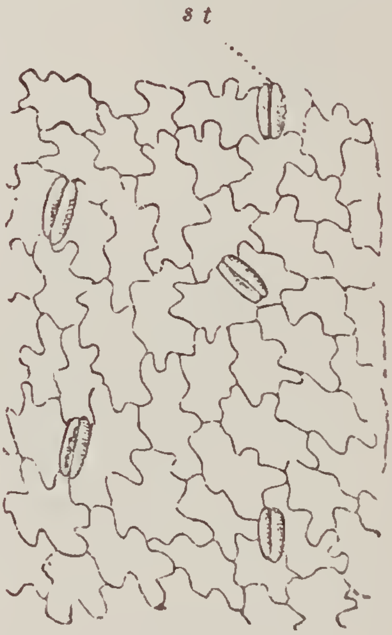

Fig. 87.

Fig. 87.—Stomata *s t*, or openings in the epidermis or skin of the leaf of Balsam. There are five of these represented in the figure, placed at regular intervals. They are connected especially with the exhalation of fluids.

vary much in their form and appearance in different plants.

In the form and size of leaves we may perceive many interesting adaptations. Thus the large fan-shaped leaves of palms are fitted for shade and shelter in the warm countries in which they grow; while the narrow leaves of pines and firs fit them for the alpine districts in which storms and blasts prevail. In leaf-buds, also, wonderful provision is made by the Creator for the preservation of their contents. They are a sort of winter-quarters, in which the young leaves and branches are nursed. With this view they are covered with coarse external leaves, or with a coating of gummy or resinous matter. It is only when the genial warmth of spring calls them forth that they burst their cerements, and expand their delicate structures to the air. Our native plants protrude their leaves cautiously, and thus are seldom injured much from our variable springs; but exotics transplanted from temperate climes, where spring is continuous, and there are no nipping frosts to arrest growth, are often, as it were, deceived by a few days of warmth in our northern climate, put off their winter clothing too soon, and thus suffer severely for their temerity. The time of putting forth the leaves indicates the nature of the seasons, as well as the time of falling of the leaves.

The function of the leaves is to expose the juices of the plants to light and air, and thus to aid in forming the woody matter of the stem, and the various secretions. Unless the leaves are freely exposed to air and light, the wood is not properly formed. Hence the reason why the wood is deficient both as regards quantity and quality in trees grown in crowded plantations. The same observations apply to all the secretions of plants. Thus potatoes grown in the shade, by which the functions of their leaves are impeded, become watery, and produce little starch in their tubers. Leaves also give off a quantity of watery fluid. This constitutes what is called exhalation. The amount of fluid exhaled varies according to the structure of the leaves and the nature of the climate. When the texture of the leaf is hard and dry, as in some Australian plants, or the skin covering the leaf is thick and dense, and has few stomata, as in the American aloe and in the oleander, the exhalation is comparatively small. In this way certain succulent plants, as cactuses, are enabled to withstand the effects of dry and hot climates without being dried up by the great loss of fluid from exhalation.

The thick covering of hairs, as well as the waxy coating on some leaves, seem to be connected with the amount of exhalation. Some very hairy plants have been known to withstand the effect of great and continued drought.

"Plants exhale fluid from their leaves, in the first place, for their own benefit. But various important secondary effects follow from this process. One of these is maintaining a suitable portion of humidity in the air. Not only do they attract and condense the moisture suspended in the air, and borne by the wind over the earth's surface, which, falling from their leaves, keeps the ground below moist and cool; but they can, by means of their roots, pump it up from a very considerable depth, and, raising it into the atmosphere, diffuse it over the face of the country. Trees, by the transpiration from their leaves, surround themselves with an atmosphere constantly cold and moist. They also shelter the soil from the direct action of the sun, and thus prevent evaporation of the water furnished by rains." In this way they contribute, as Humboldt states, to the copiousness of streams. When forests are destroyed, as they are everywhere in America by the European planters, with an imprudent precipitation, the springs are entirely dried up, or become less abundant. The inconsiderate felling of woods, or the neglect to maintain them, has changed regions noted for fertility into scenes of sterility. The droughts which so often visit the Cape de Verd Islands are attributed to the removal of their forests. A disregard of this point may do great harm to Australia—a country where drought is already sufficiently injurious. In wooded countries, where the rains are excessive, as in Rio Janeiro, the climate has been improved by the diminution of the trees.

Another and most important function of leaves is to keep up the purity of the atmosphere. A poisonous gas, called carbonic acid gas, is constantly sent into the air by the breathing of man and animals, and by the various processes of combustion; and this gas is decomposed by leaves and the green parts of plants, under the influence of light. They are thus enabled to separate the carbon for their own use as food, and to give out oxygen gas, which constitutes the part of the air necessary for breathing. The carbonic acid gas exhaled from the lungs of a single individual in 24 hours contains, on an average, 5 to 8 ounces of carbon—a substance familiar to all in the form of wood-charcoal. A full-grown man, therefore, will give off from his lungs, in the course of a year, 110 to 180 pounds of carbon in the form of carbonic acid. "If we suppose," says Professor Johnston, "each individual of Great Britain, young and old, to expire only 80 pounds of carbon in a year, the 20 millions would emit 700,000 tons; and allowing the cattle, sheep, and all other animals to give off twice as much more, the whole weight of carbon returned to the air by respiration in this island would be about 2 millions of tons." Besides this, we must take into calculation the quantity derived from the combustion of about 20 million tons of coals, in order to ascertain the amount to which the atmosphere in Britain is vitiated. All the carbon is employed in the growth of plants. The exhalation from the leaves of plants grown in ordinary rooms is so great that the plants will not thrive. To obviate this, and to prevent the effects of the noxious gases and smoke of towns from injuring the plants, Mr Ward invented glass cases, which bear his name, in which cultivation may be carried on successfully (fig. 88). In these Cases, the water exhaled from the leaves is condensed on the glass and falls down again. Ferns succeed remarkably well in such Cases.

The leaves of plants growing vigorously are thus made subservient by the all-wise Creator to most important ends. The carbon, which in its combination with oxygen is so deleterious, is an important ingredient in plants, and is taken up by them in the form of carbonic

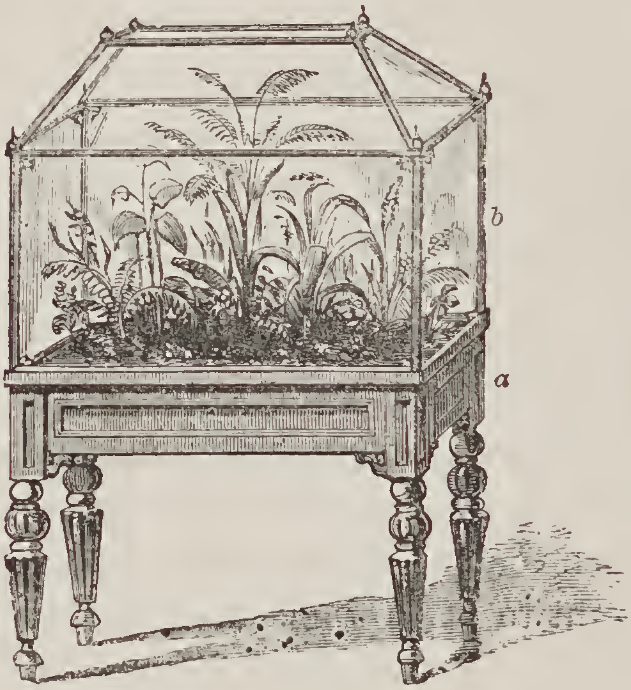

Fig. 88.

Fig. 88.—A Wardian Case for a drawing-room, consisting of a strong wooden box or trough *a*, supported on a stand, and covered with a glazed frame *b*. The box is filled with loam, sand, and peat, laid over a layer of gravel and broken bricks. Water is freely poured over the soil at first, and it is allowed to drain off by means of two holes in the bottom of the box, which are subsequently stopped up with corks. After the plants have been put into the soil, the glazed frame, made of wood, zinc, or brass, is fitted on carefully in a groove on the upper part of the box. In the frame there is a glass door for the purpose of allowing the removal of dead leaves, and of permitting air to enter freely when the atmosphere in the case is too moist.

acid. Plants of warm climates, with large evergreen leaves, and under the blaze of a tropical sun, contribute to supply the pure air to other regions where the leaves fade and the light is deficient. Liebig says:—"The proper, constant, and inexhaustible sources of oxygen gas are the tropics and warm climates, where a sky seldom clouded permits the glowing rays of the sun to shine upon an immeasurably luxuriant vegetation. The temperate and cold zones, where artificial warmth must replace the deficient heat of the sun, produce, on the contrary, carbonic acid in superabundance, which is expended on the nutrition of the tropical plants." It is only during light that leaves have their decomposing power. During the night no such process goes on; and if they are kept long in darkness, leaves lose their green colour, become pale and sickly, and deteriorate the air.

The functions of animals and vegetables may be thus contrasted:—

AN ANIMAL is	A VEGETABLE is
An apparatus of combustion or oxidation.	An apparatus of reduction or deoxidation.
Possesses the faculty of locomotion.	Is fixed.
Burns carbon.	Reduces carbon.

AN ANIMAL	A VEGETABLE
Gives off carbonic acid.	Fixes carbonic acid.
Consumes oxygen, starch, gum, and sugar.	Produces oxygen, starch, gum, and sugar.
Produces heat.	Absorbs heat.
Restores its elements to air and earth.	Derives its elements from air and earth.
Transforms organised into mineral matter.	Transforms mineral into organised matter.

In ponds and lakes we find the balance between animal and plant life kept up. So also in artificial aquariums or vivariums. The plants, under the action of light, decompose the carbonic acid given off by the animals, and produce oxygen gas, which aerates the water.

The history of a particle of carbon, in its relation to the mineral world, and to vegetable and animal life, has been thus given by Dr Gladstone:[*]—"Could we trace the history of a particle of carbon, it would, doubtless, be most romantic. It might be something of this sort. It first saw the light ages and ages ago, issuing from the mouth of a volcano as carbonic acid (CO_2). Over the earth it flew and visited the stormy clouds; and, as descending it swept along the sea, it was dissolved by the briny wave. It soon became part of a coral rock. The coral reef was raised by gradual upheavals, till it stood high and dry above the water. The tiny inhabitants of course were dead, but their solid abodes became a limestone rock. There our particle of carbon, as carbonic acid in close embrace with a particle of lime, was stored up for unnumbered ages. The rock was afterwards quarried, and from the lime-kiln it was expelled, again to take its flight over the green earth, till, caught up by a vigorous rose tree, it became decomposed and stowed away in the green covering of its leaves. Here a caterpillar ate it, and it formed part of its tiny body. As the winter came on it was hung up in a dry, stiff chrysalis, which, as the warm spring gladdened the earth, was split open, and from it our carbon escaped a part of a new-winged, many-coloured butterfly. The butterfly died, and his little corpse was picked up by a bird; but scarcely had our atom become assimilated by the bird, when it came roasted to the table of a man. Into his stomach and through his arteries our particle passed, till, stored up in the muscle, it lent itself to add strength to his right arm; but this muscle was ever changing, and soon it is given up again to the blood and burned in his veins, and is breathed forth from his lungs. Away now it is flying once more, to take part in wonderful transformations. There is thus formed a great circle, one link of which is the atmosphere. The animal and vegetable kingdoms are not antagonistic, but mutually dependent. The more plants the earth supports the more animals can be fed. And again the breathing and death of animals contribute to the life of the plant. We see something of the wisdom by which this arrangement has been contrived; but who shall solve the intricate question involved in the management of the whole? (Ps. cxlv. 15, 16)."

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[*] Excelsior, i. 119.

The heat and light required for the growth of plants does not disappear, but is treasured up for after use. Dr George Wilson remarks:—"Daily the conviction deepens among those who have studied the matter, that, with a few exceptions, all the physical powers which man wields as movers or transformers of matter are modifications of sun-force. It was bestowed upon antediluvian plants, and they locked it up for a season in the woody tissue which it enabled them to weave, and afterwards time changed that into coal; and the steam-engine which we complacently call ours, and claim patents for, burns that coal into lever-force and steam-hammer power, and is, in truth, a sun-engine. And the plants of our own day receive as liberally from the sun, and condense his force into the charcoal which we extract from them, and expend in smelting metallic ores.

"And again, the plants we cultivate concentrate sun-force in grass, hay, oats, wheat, and other fibres and grains, which seem only suitable to feed cattle and beasts of burden with. But by and by a Spanish bull-fighter is transfixed by this force, through the horns of a bull, and dies unaware of his classical fate, pierced to the heart by an arrow from Apollo the sun-god's bow. On English commons prizes are run for, by steeds which are truly coursers of the sun, for his force is swelling in their muscles and throbbing in their veins, and horse-power is but another name for sun-power. Nor is it otherwise with their riders; for they, too, have been fed upon light, and made strong with fruits and flesh which have been nourished by the sun. His heat warms their blood, his light shines in their eyes; they cannot deal a blow which is not a *coup de soleil*,—a veritable sunstroke; nor express a thought without help from him.

"As force cannot be annihilated any more than matter, but can only be changed in its mode of manifestation, so it appears beyond doubt that the force generated by the sun, and conveyed by his rays in the guise of heat, light, and chemical power, to the earth, is not extinguished there, but only changes its form. It apparently disappears when it falls upon plants, which never grow without it; but we cannot doubt that it is working in a new shape in their organs and tissues, and reappears in the heat and light which they give out when they are burned. This heat, which is sun-heat *at second hand*, we again seem to lose when we use plants as fuel in our boiler-furnaces; but it has only disguised itself without loss of power, in the elasticity of the steam, and will again seem lost, when it is translated into the momentum of the heavy piston, and the whirling power of a million of wheels."

The functions of leaves may be used to illustrate the Christian life. The world lieth in darkness in the wicked one (1 John v. 19). Satan is the prince of the power of the air (Eph. ii. 2), and he has poisoned the moral atmosphere. The people of God are the children of the light and of the day; they are not of the night nor of darkness (1 Thes. v. 5). A new life is imparted to them, and the light of the glorious Gospel has shined into their hearts (2 Cor. iv. 4-6). They live in the shining of the

Sun of Righteousness, who has arisen upon them with healing in His wings (Mal. iv. 2). So long as they are in His light, they are green and vigorous; and they are made the means, in His hand, of purifying the spiritual air. They make their light shine before men, that others, seeing their good works, may glorify their Father who is in heaven (Matt. v. 16). Their presence on the earth is made by God the reason of His sparing the inhabitants thereof. Ten righteous would have saved Sodom (Gen. xviii. 32). How little do the world think of what it owes to the despised people of God! Of themselves, however, they can do nothing: it is only in the light of Christ. If left in darkness, they would pollute the atmosphere. The more fully the Sun of Righteousness shines on them, the more spiritual vigour and growth do they display. Often He hides His face under a cloud, but still there is light; and although in such seasons their faith may languish, yet it will revive, for the clouds and mist shall pass away, and there will be, as it were, the clear shining after rain (2 Sam. xxiii. 4).

It has been already mentioned that the green colour of leaves is due to the action of light, and that when kept long in darkness they become pale. In preparing certain delicacies for the table, the gardener blanches plants, that is to say, he makes them grow in darkness, or at least partially covered from the light. In this way the plants lose their green colour, and they do not form their proper secretions. In place of woody fibres, only delicate cells and spirals are produced, and the plants are rendered tender. Thus the leaf-stalks of celery and sea-kale and the shoots of asparagus are made fit for use. The heart of the cabbage is rendered white and delicate by the outer leaves screening it from light. By the same process the odours of plants are weakened or destroyed.

Leaves exhibit peculiar forms in consequence of being folded so as to produce what are called pitchers. There are various kinds of pitcher-plants. The pitcher of an American pitcher-plant (*Sarracenia*) is represented in fig. 89, while that of an East Indian plant (*Nepenthes*) is seen in fig. 90. In the latter there is a distinct lid, which is folded over the mouth of the pitcher at first, but ultimately rises, as shown in the woodcut. The fluid in the pitcher before the lid opens contains certain saline matters in solution. One of the Indian pitcher-plants, called *Dischidia Rafflesiana*, climbs to the top of the lofty trees and produces pitchers only among the upper leaves. There it is that the plant sends out little rootlets which enter the pitchers and derive nourishment from the rain and dew which are thus collected. So it is that in rising to places of eminence and distinction, we ought ever to carry with us that reservoir of Truth, whence alone we can derive the precious dews of heaven, to refresh and invigorate our souls. Sometimes the leaf is folded so as to form a completely closed cavity, as in the onion. The leaf-stalk becomes often inflated with air cavities, in order to float the leaf, as in Pontederia, and the size of the petiole varies according as the plant grows in shallow or deep water. When the roots reach the

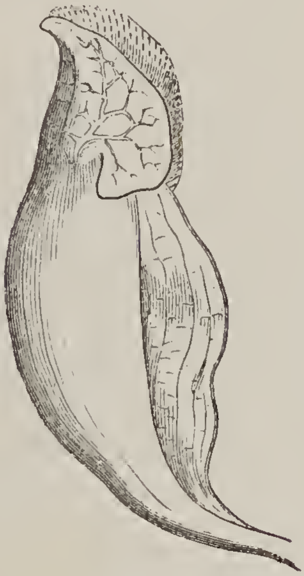

Fig. 89.

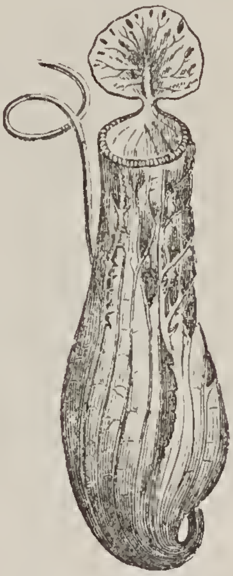

Fig. 90.

Fig. 89.—Pitcher of *Sarracenia purpurea*, a North American marsh plant.

Fig. 90.—Pitcher of *Nepenthes distillatoria*, from the Indian Archipelago. It hangs by a narrow portion of the leaf-stalk or petiole, and has a distinct lid which closes the orifice at first.

mud then there is little air in the leaf-stalk; when, however, the root hangs in deep water, the quantity of air is much increased, as it is then specially required for floating the plant.

Leaves are usually arranged under the heads of simple and compound, the former having a blade composed of one piece either perfectly entire or divided in various ways, and having no joint beyond the point where they are united to the stem (figs. 91, 92, and 93); the latter having a blade divided into separate pieces or leaflets, which are united by joints to the petiole or leaf-stalk (figs. 94 and 95). The joints appear as swellings of various sizes, into the composition of which cellular tissues enter largely. Changes in the contents of

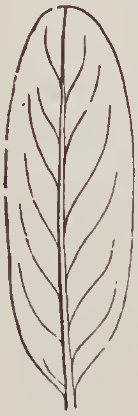

Fig. 91.

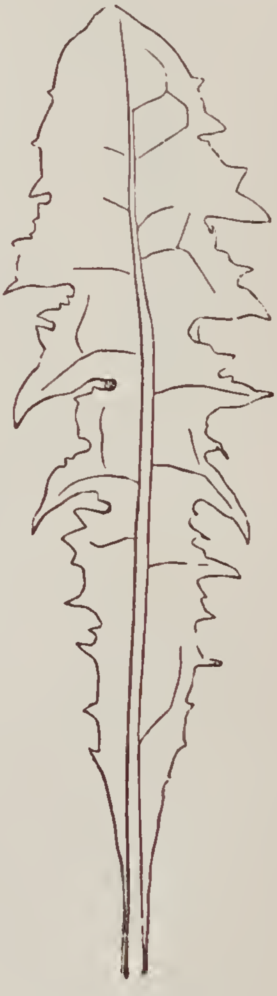

Fig. 92.

Fig. 91.—Simple oblong leaf of a species of Senna. The apex is obtuse or blunt, and the base is unequal.

Fig. 92 —Simple runcinate leaf of Dandelion (*Leontodon Taraxacum*), It is a pinnatifid leaf, with the divisions pointing towards the petiole.

the cells give rise to various movements, which have been included under the name of irritability of leaves. Compound leaves frequently display evident movements under the influence of light and heat, as well as of mechanical and chemical stimuli. The effects of light and darkness are often rendered evident by the elevation or depression of the leaf-stalk, and by the expanding and folding of the blades of the leaf. The folding of leaves during darkness has been called the sleep of plants. It is seen in most plants with leaves called pinnate, as repre-

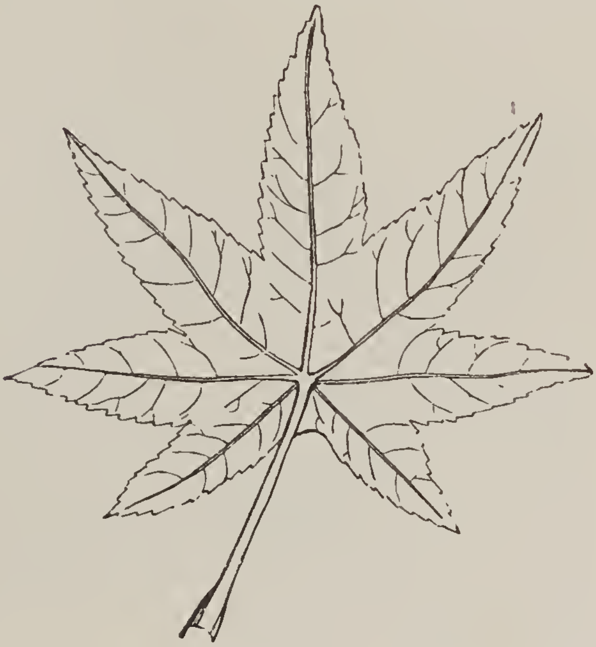

Fig. 93.

Fig. 93.—Simple leaf of Castor-oil plant (*Ricinus communis*). It is palmately-cleft, and exhibits seven lobes at the margin. The petiole or leaf-stalk is inserted a little above the base, and hence the leaf is called peltate or shield-like.

sented in fig. 94; as well as in those having ternate leaves, such as the wood-sorrel (fig. 96).

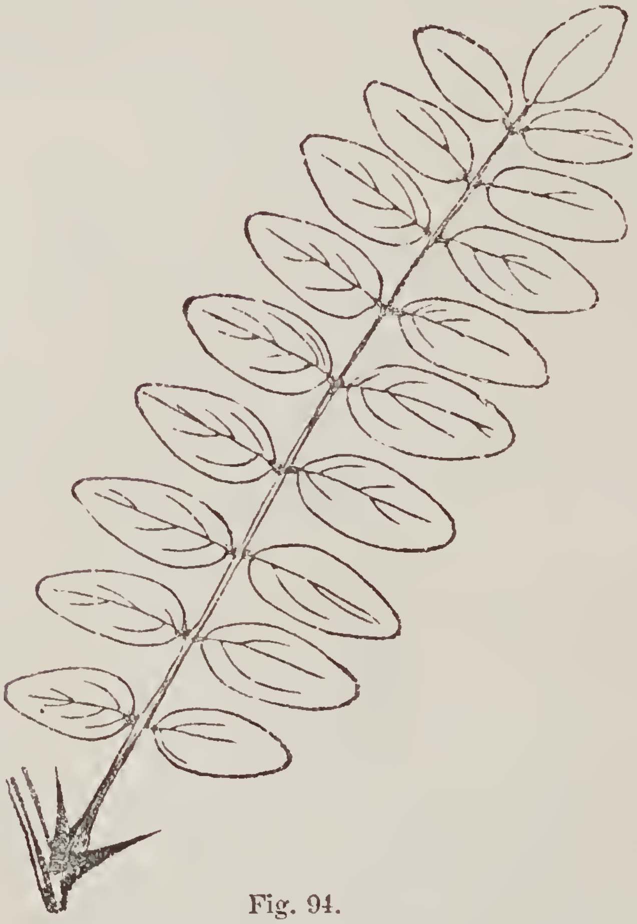

Fig. 94.

The leaves of *Porliera hygrometrica* close on the approach of rain.

In the plant called Venus's Fly-trap (fig. 97), the leaf is furnished with three projecting hairs on its blade, as seen in the expanded leaf *a*, which, when touched, immediately cause

Fig. 94.—Compound impari-pinnate (unequally pinnate) leaf of Robinia. There are nine pairs of shortly-stalked leaflets (*foliola*, *pinnæ*), and an odd one at the extremity. At the base of the leaf stipules are seen.

the leaf to fold upon itself (fig. 97, *l*), and thus enclose any insect that may have alighted on it. In the sensitive-plant (fig. 98), the slightest touch causes the little leaflets to fold together in the way shown in the figure, and if the irritation is continued, the whole leaf falls down. These movements may be induced by the action of ether, chloroform, prussic acid, and

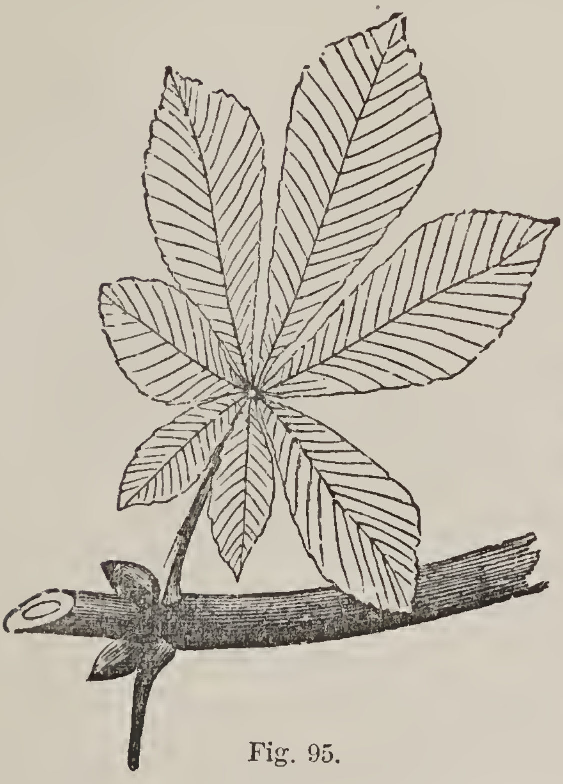

Fig. 95.

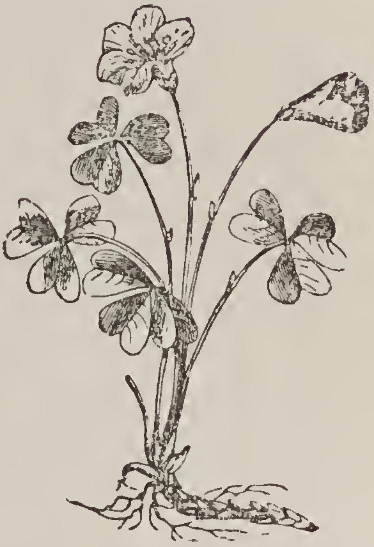

Fig. 96.

Fig. 95.—Compound septenate leaf of the Horse-chestnut (*Æsculus Hippocastanum*). Such leaves, especially when there are five leaflets, are called digitate.

Fig. 96.—Wood-sorrel (*Oxalis Acetosella*), with its compound ternate leaves, which are said to display a certain amount of irritability when exposed to bright sunshine. During the night each of the three leaflets, forming the compound leaf, fold on their midrib, and then fall down towards the common petiole. Some say that this plant is the true Irish Shamrock.

many other substances. If the cause of irritation is removed, and the plant is left undisturbed, it gradually recovers its natural state. During the night, the leaflets close, and the leaf is depressed. In the Moving-plant of India (*Desmodium gyrans*), as shown in fig. 99, there are two little leaflets which are in constant motion, jerking from one side to the other in a remarkable manner, both during light and darkness. The large leaf at the end of the stalk also exhibits slow movements, rising and falling, and moving from one side to the other. During darkness, the large leaf always hangs down. These remarkable movements exhibited by the leaves of plants are not dependent on nervous and muscular power, as is the case in animals, but they seem to be

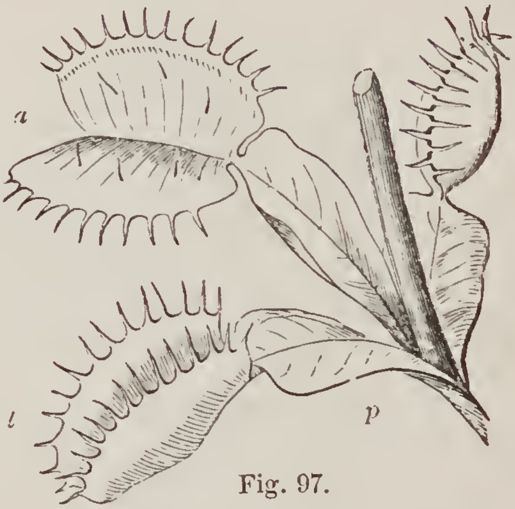

Fig. 97.

Fig. 97.—*Dionæa muscipula*, Venus's Fly-trap, a North American marsh-plant, which displays irritability of its leaves. One leaf *a* is expanded, showing the two parts of the blade with three projecting hairs on each, which, when touched, cause the parts of the blade to fold, as shown in the other two leaves. The petiole or leaf-stalk *p* is broad, and is called winged. A partially closed blade of the leaf is marked *l*.

caused by the greater or less distension of cells connected with the bases of the leaves and of the leaf-stalks.

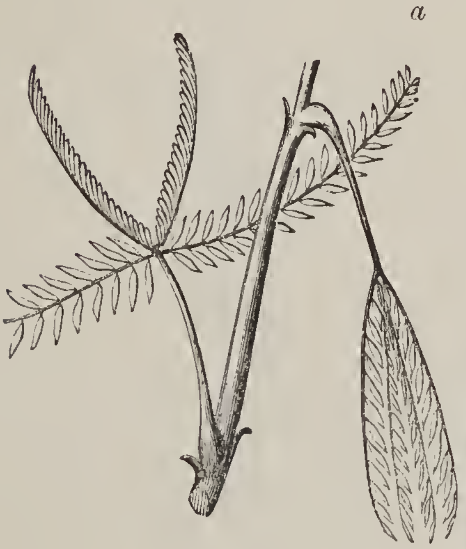

Fig. 98.

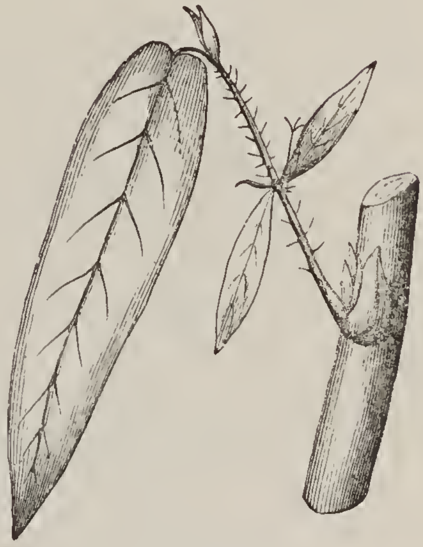

Fig. 99.

The mode in which leaves are arranged on the stem deserves notice. They are either placed opposite to each other, as seen in fig. 100, or alternate with each other, as in figs. 101 and 103. When leaves are opposite, we frequently find that the different pairs cross each other at right angles. Thus in fig. 100, the two leaves

Fig. 98.—*Mimosa pudica*, Sensitive-plant. The stem with two leaves. Each leaf is composed of numerous leaflets on a common stalk. In the lower leaf the leaflets are expanded at one part and closed at the other. In the other leaf all the leaflets are closed and the whole leaf has fallen down.

Fig. 99.—*Desmodium* or *Hedysarum gyrans*, the Moving-plant of India. The large leaf moves slowly and imperceptibly from side to side, as well as upwards and downwards. The little leaflets are constantly jerking so as to meet in the middle and then separate again.

at the base are placed to the front and back, the next two right and left, and so on. When several occur at the same level, they become whorled or verticillate (fig. 102), and then the leaves of the separate whorls alternate with each other. There is thus seen a law of alternation. The alternate position of leaves seems to be connected with the formation of the woody matter of the stem, and with their free exposure to air and light. This law of alter-

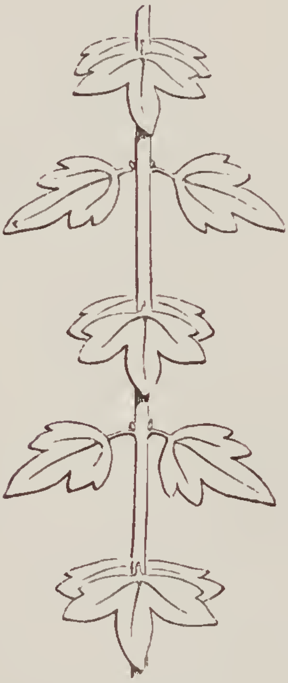

Fig. 100.

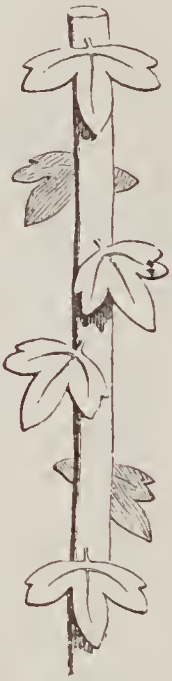

Fig. 101.

Fig. 100.—Opposite leaves on a stem, each pair is placed at right angles to that next it, thus following a law of alternation.

Fig. 101.—Alternate leaves. The sixth is placed directly above the first, and the fraction expressing the arrangement is $\frac{2}{5}$, viz., two turns round the stem and five leaves.

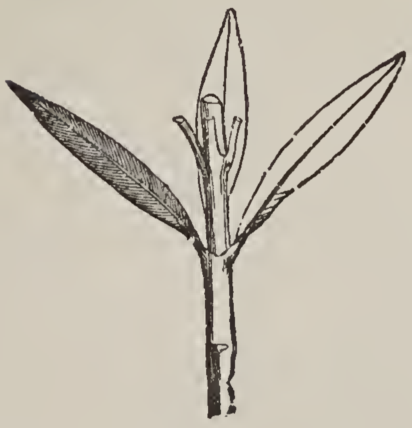

Fig. 102.

nation is distinctly visible in the case of single leaves produced at each point of the stem. In fig. 101 there are six leaves arranged at different heights on the stem, and it will be seen that the sixth leaf is directly above the first, and the same thing is seen in fig. 103, where the leaves are numbered in succession, 1, 2, 3, 4, 5, 6. Commencing with the lowest leaf in these figures, and proceeding regularly through all the leaves until we reach the one directly above the first, we follow a spiral direction, make two complete turns round the stem, and pass through five leaves. This arrangement is expressed by the fraction $\frac{2}{5}$. In figs. 104 and 105, it is shown that in the case of alternate leaves, perpendicular lines may be drawn through the leaves placed directly over each other, and the number of these lines indicates the number of leaves in each spiral cycle, or the number of leaves between any leaf on the stem and that directly above it. In both these

Fig. 102.—Acute leaves of Rose-bay (*Nerium Oleander*), arranged in a verticil or whorl of three in the young state.

figures it will be seen that the number of these lines is seven, and this, therefore, is the number of leaves in each cycle. But it will also be noticed that the number of turns made round the stem in completing the cycle is different. Thus, in fig. 104, commencing with leaf No. 1, we reach leaf No. 8, or that directly above 1, after making three turns round the stem, and the fraction indicating this is $\frac{3}{7}$; whereas in fig. 105 we reach No. 8 after one turn, and the fraction therefore is $\frac{1}{7}$. These fractions mark the angular divergence between

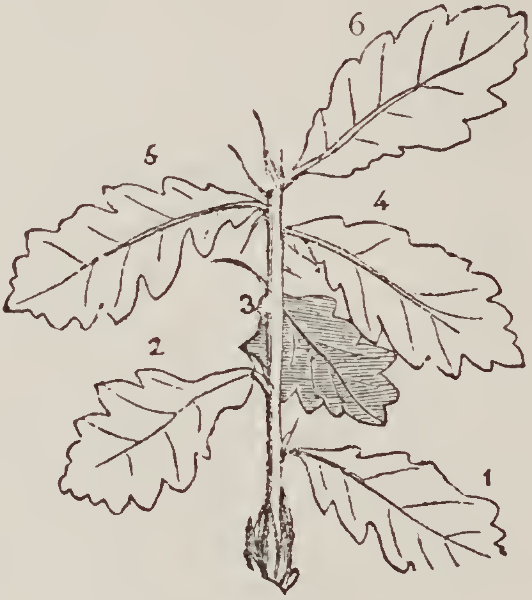

Fig. 103.

Fig. 103.—Alternate leaves, arranged in the same way as in fig. 101, the number expressing the arrangement being $\frac{2}{5}$. The sixth leaf is directly above the first, and there are five leaves in the cycle.

any two leaves of the cycle, as represented in the divided circles at the upper part of the stems. In fig. 104, between 1 and 2 the angular divergence is obviously $\frac{3}{7}$, while in fig. 105 it is $\frac{1}{7}$ of the circle.

There is thus a spiral coil consisting of a certain number of leaves. The cycle being determined by the leaf directly above that from which we start. The number of leaves in a cycle varies according to the series, 1, 2, 3, 5, 8, 13, 21, 34, 55, etc., where it will be seen that each successive number is made up of the two preceding. It is also observed that in pass-

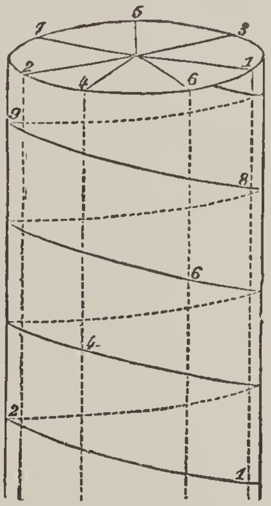

Fig.104.

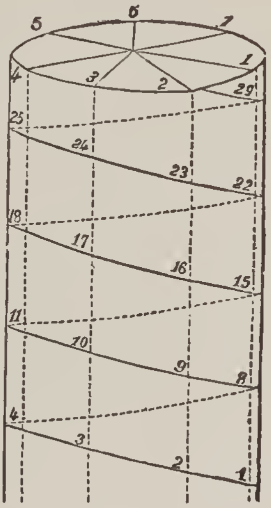

Fig. 105.

Figs. 104 and 105.—Diagrams to illustrate the arrangement of the leaves on the stem. In each figure the cycle consists of seven leaves. In 104 the divergence between every two leaves is $\frac{3}{7}$ of a circle, or $\frac{3}{7}$ of 360°=154$\frac{2}{7}$. In 105 the divergence between every two leaves is $\frac{1}{7}$ of 360°=51$\frac{3}{7}$.

ing through the leaves forming the cycle the number of turns which the spiral takes varies according to the same series of numbers. The fraction expressing their arrangement necessarily indicates the angle of divergence between any two leaves of the cycle — the divergence or horizontal separation of two leaves being measured by the arc of a circle corresponding to an angle of which the summit is in the centre of the branch (fig. 106). Thus we arrive at a series of fractions, $\frac{1}{2}$, $\frac{1}{3}$, $\frac{2}{5}$, $\frac{3}{8}$, $\frac{5}{13}$, $\frac{8}{21}$, $\frac{13}{34}$, $\frac{21}{55}$, and so on. These numbers are all brought out by the continued fraction—

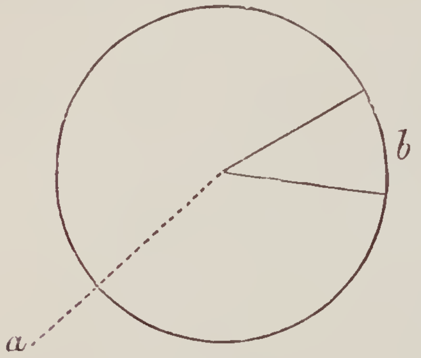

Fig. 106.

$$\frac{1}{2+\frac{1}{1}+\frac{1}{1}+\frac{1}{1}+\frac{1}{1}\cdots\cdots}$$

In going from one leaf to that which immediately follows, we perceive that there are usually two roads, the one long and the other short, according as we proceed in one direction or in the opposite. Suppose the leaves separated by the divergence of $\frac{8}{21}$, if we take the long road we shall find the divergence to

Fig. 106.—*a* indicates the angle of divergence between two leaves, and *b* the arc of the circle which measures it.

be the complementary angle of $\frac{8}{21}$ as regards the entire circumference considered as unity; that is to say, it will be $\frac{13}{21}$. By changing in the same way all the divergences of the series we obtain another complementary series of fractions, viz.,—$\frac{1}{2}$, $\frac{2}{3}$, $\frac{3}{5}$, $\frac{5}{8}$, $\frac{8}{13}$, $\frac{13}{21}$, $\frac{21}{34}$, $\frac{34}{55}$, and so on. These all arise from the continued fraction—

$$\frac{1}{1+\frac{1}{1}+\frac{1}{1}+\frac{1}{1}\cdots\cdots}$$

The series is continued indefinitely by taking for the numerator the term which in the series 1, 2, 3, 5, 8, 13, 21, etc., precedes by a single stage the denominator.

We thus perceive, that a series of vertical lines may be drawn passing through leaves which are placed directly over each other (figs. 104 and 105). If we can count five vertical rows, then we refer the arrangement to $\frac{2}{5}$; if 8, to $\frac{3}{8}$; and if 13, to $\frac{5}{13}$; and so on. When leaves are very crowded, the vertical ranks are not so evident as two or more rows of oblique or secondary spirals, which are seen winding in opposite directions. Thus in the House-leek (fig. 107), we see several secondary spirals as indicated by numbers 1, 6, 11; 3, 8; 4, 9, 14, 19; and 12, 17, winding to the left; and numbers 1, 9, 17, winding to the right. The oblique rows are the necessary consequence of a regular ascending arrangement of parts with equal intervals over the circumference of the axis. The leaves, when numbered, are in arithmetical progression—having a common difference. In the numbers just given these differences are 5 and 8. When we look on the top of such a leaf arrangement we see a shortened axis, as in fig. 108, A, with a series of leaves coming off from it in a spiral manner.

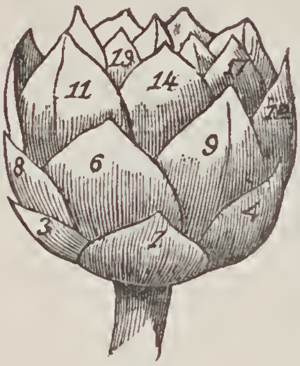

Fig. 107.

When the distances between the leaves are very short, so that they are in close approximation, we can see the superposition, but it is difficult to follow the succession of intermediate leaves, and to ascertain the generating or primary spiral running through every leaf. This may be done by attending to the number of vertical ranks and the secondary spirals. The number of the latter represents the common difference as regards number between the leaves composing them. Thus, in fig. 107, there are five secondary spirals running in one direc-

Fig. 107.—An offset of the House-leek (*Sempervivum tectorum*) showing a rosette of leaves placed in the $\frac{5}{13}$ arrangement. The fourteenth leaf is directly above the first. The secondary spirals are seen running in different directions.

tion, and the common difference of the scales in these spirals is five, and there are eight in another direction, where the common difference is eight, and so on. Secondary spirals are well seen in the rosette of the house-leek (fig. 108), or of the *Sempervivum tabulariforme*, and in the leaflets of the receptacles of composite plants, such as the artichoke scales. They may also be traced in the scales of cones, which must be looked on as modified leaves. In the cone there is a generating spiral going

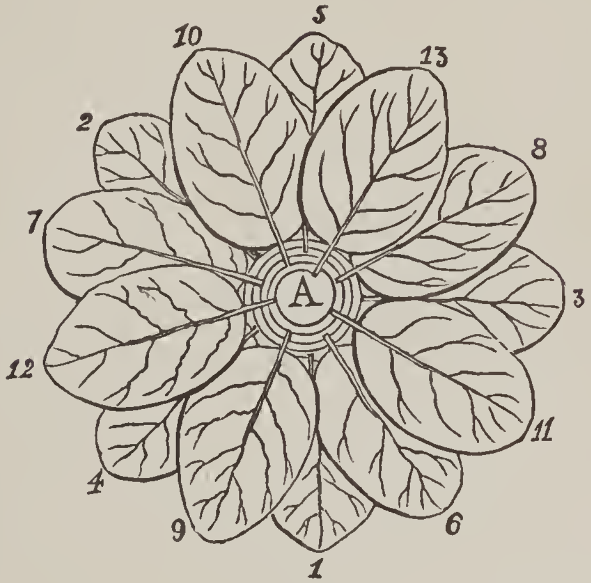

Fig. 108.

Fig. 108.—Rosette of leaves of the House-leek (*Sempervivum tectorum*), showing a cycle of thirteen leaves, indicated by the fraction $\frac{5}{13}$. The observer is supposed to be looking downwards at the top of the rosette. There is a short axis A bearing the leaves. On this axis there have been described five revolutions of the spire, and the origin of each of the thirteen leaves is indicated.

through all the scales, which are placed at equal distances on the spiral. There are also evident secondary spirals running in two directions, from right to left, and from left to right. By the intersection of these spirals beautiful rhomboidal figures are formed,—a series of quincunxes are produced. The number of spirals in the different sets follow the numerical series already noticed, 1, 2, 3, 5, 8, etc.; and if there be a certain number of these spirals or cycles going in one direction, as from right to left, then those going from left to right will be, as regards number, always one or other of the contiguous numbers in the series mentioned. The number of spirals in the intersecting sets are always 1 and 2, or 2 and 3, or 5 and 8, or 8 and 13, or 13 and 21, or 21 and 34, etc. Thus, if the number in the one set going from right to left is 5, then the number in the other set proceeding from left to right will be either 3 or 8. Dr M'Cosh, who has examined this subject particularly, says, that in cones of pines and firs, all the spirals in one of the sets—and that invariably the one which has the highest number—take usually one turn in going from the base to the top of the cone; that is, each goes round the cone once, and stops at the apex perpendicularly over the part from which it started. Thus, if the spirals be 8 and 5, then each of the 8 will be found to have taken one complete turn before it reaches the apex; and if the number be 13 and 8, then the 13 will be found to have twisted themselves once round the axis. This seems to be the rule in the set of spirals containing the large number. The other set appears also to have a rule. In the cone with the ordinary relation between the height and width, that is, where the circumference is greater than the height, the number of turns made by the set of spirals of the lower number is 2; or, in other words, the spiral goes twice round the axis before reaching the apex. But in cones whose height is great in proportion to their width,—whose length is greater than their circumference,—as in the Weymouth pine, Pinaster, Douglas pine, and others, the number of turns taken by the spiral is three.*

In the cone of the American larch (fig. 109), we have the quincuncial arrangement of scales marked by the fraction $\frac{2}{5}$. There are five vertical ranks, as marked in the tabular numerical view at the side of the cone, viz.,—2, 7, 12; 4, 9, 14; 1, 6, 11; 3, 8, 13; 5, 10, 15, the common difference being 5.

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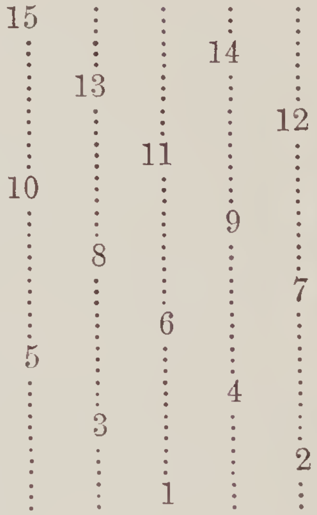
* M'Cosh and Dickie, Typical Forms, p. 128.



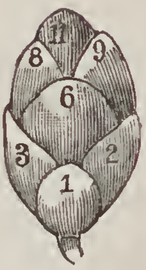


Fig. 109.

On looking at the cone we find also parallel oblique ranks, two of which, ascending to the left, are marked by the numbers 1, 3, 5, which, if the diagram is coiled round a cylinder, continue in the numbers 7, 9, 11, 13, 15; and 2, 4, 6, 8, 10, continued into 12, 14. There are thus two left-handed spirals, with 2 as the common difference in the numbering of the scales. This number corresponds with the number of oblique parallel spirals on this side. Again, three oblique parallel spirals ascend to the right, marked by numbers 1, 4, 7 running into 10, 13; 3, 6, 9, 12 going on to 15; and 5, 8, 11, 14. Here the common difference in the numbering of the scales is 3, corresponding with the number of the oblique right-handed spirals. Again, in the white pine (*Abics alba*) the $\frac{5}{13}$ arrangement is seen (fig. 110). Here we can

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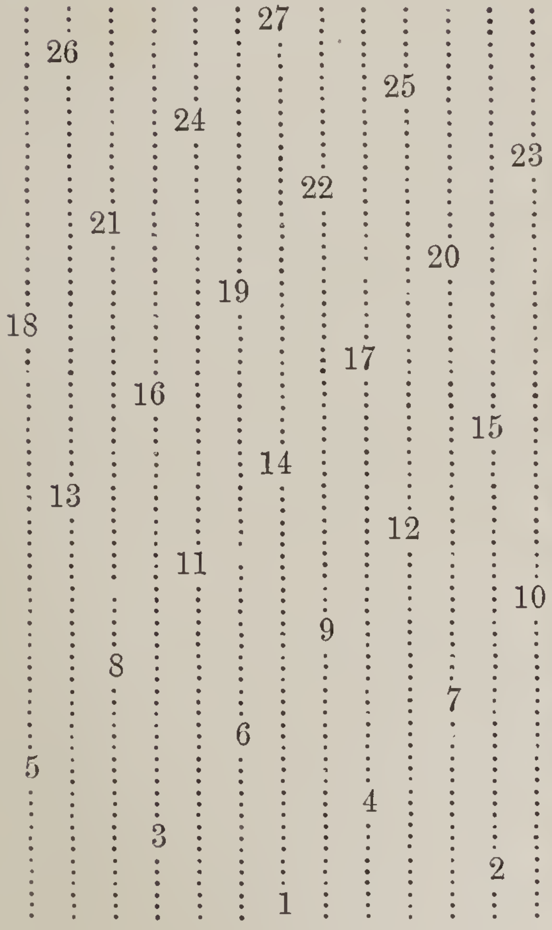
Fig. 109.—Cone of a species of Larch (*Larix microcarpa*), taken from Professor Asa Gray's work, with the scales numbered, so far as seen. The arrangement is $\frac{2}{5}$ in the five-ranked series. There are five vertical rows of scales, 1, 6, 11; 4, 9, 14; 2, 7, 12; 5, 10, 15; and 3, 8, 13, as shown in the annexed diagram.

trace (as shown in the tabular view) five vertical lines passing through scales placed directly over each other, with the common

Vertical Projection of the $\frac{5}{13}$ Arrangement.



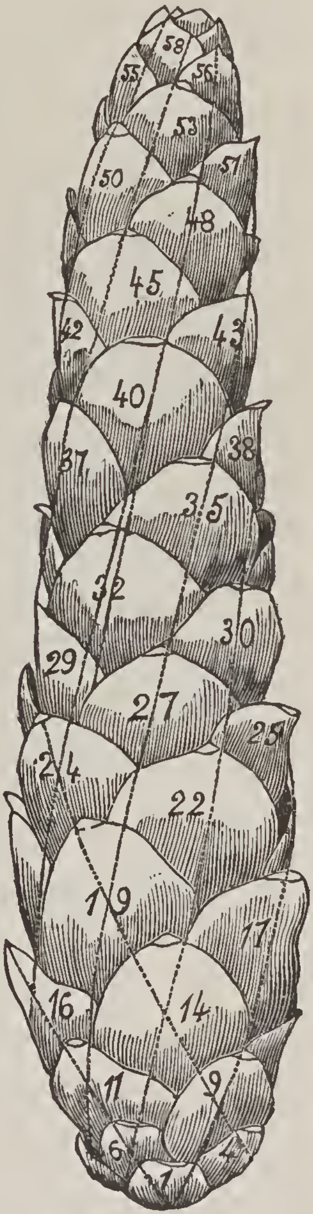


Fig. 110.

Fig. 110.—Cone of the White Pine (*Abies alba*), on which the scales are numbered, so far as seen, and the leading secondary spirals are

difference 13,—viz., 10, 23; 2, 15; 7, 20; 12, 25; 4, 17; 9, 22; 1, 14, 27; 6, 19; 11, 24; 3, 16; 8, 21; 13, 26; 5, 18. In the same way we see secondary spirals running parallel to the right and the left. There are eight oblique spirals going to the right, with the common difference 8,—viz., 1, 9, 17, 25; 6, 14, 22, 30, 38; 3, 11, 19, 27, 35, 43, 51; 8, 16, 24, 32, 40, 48, 56; 2, 10, 18; 4, 12, 20; 5, 13, 21; 7, 15, 23. Besides these, there are also seen five parallel oblique spirals winding to the left, with the common difference 5,—viz., 1, 6, 11, 16, 21, 26; 4, 9, 14, 19, 24; 2, 7, 12, 17, 22, 27; 10, 15, 20, 25; 3, 8, 13, 18. The number 5 is the numerator of the fractions, and the numbers 5 and 8 added together give the denominator 13.

Cases of leaf arrangement, or, as it is called, phyllotaxis, represented by the fractions, $\frac{1}{2}$, $\frac{1}{3}$, and $\frac{2}{5}$, are most common and uniform, and most easily seen. In higher forms the exact order of superposition becomes uncertain, owing to a slight torsion of the axis. The higher numbers are thus a little to one side or the other of the

indicated. Those with the common difference 8 are marked by dotted lines ascending to the right; two of the five that wind in the opposite direction are also marked with dotted lines; the set with the common difference 3, in one direction, and that with the common difference 2, in the other, are very manifest. There are 13 vertical ranks as shown in the annexed numerical diagram. The figures at the side of the cones show a vertical projection of the $\frac{5}{13}$ arrangement up to scale 27 (Prof. Asa Gray).

vertical line. The spiral character of the arrangement is well seen in the leaves of species of Pandanus, which receive the name of *screw*-pine on account of this.

In speaking of the fractions expressing the leaf arrangement, Agassiz remarks,—"These fractions, it will be seen, do not differ much from each other. There are none of them less than $\frac{1}{3}$, and none of them more than $\frac{1}{2}$. They form a regularly ascending series, on which any two added together will make the third. Such is the uniform and careful arrangement of the countless leaves of the elms above our heads, and of the pine tree of yonder plains. Turn now from plants to planets. Measure the times in which each of these circles the sun. It is as follows :—

	Days.		Days.
Neptune,	62,000	Asterodia,	1,600
Uranus,	31,000	Mars,	680
Saturn,	10,000	Earth,	365
Jupiter,	4,330		

Now examine these series. The second is $\frac{1}{2}$ the first, the third is $\frac{1}{3}$ of the second, the fourth is $\frac{2}{5}$ of the third, the fifth is $\frac{3}{8}$ of the fourth, and the sixth is $\frac{5}{13}$ of the fifth. So that we have again precisely the same fractions in the same order, $\frac{1}{2}$, $\frac{1}{3}$, $\frac{2}{5}$, $\frac{3}{8}$, and $\frac{5}{13}$. Whence this strange simplicity? How can it be accounted for except by the fact that the same Hand adjusted the blades of grass which set in motion the orbs of the universe?"

Dr Hilgard has sought for the germ of the law of leaf-arrangement in the numerical genesis or production of cells. Starting with a primal cell, generating a second, and assuming that the second requires a time to come to maturity, during which the primal cell recovers its powers and produces a third, we have, he says, a law exhibiting the phyllotaxian numbers. One cell generates a second, and then a third; the first and second then simultaneously generate each one, which makes the whole number five. The first, second, and third, are then mature enough to generate each one, which makes the whole number eight. Five are then sufficiently mature to generate each one cell, which raises the whole number to thirteen; and so on. Thus the genesis of cells gives the phyllotaxian numbers. Then, as to position, he says, take the rosette of the houseleek, and we shall find the successive numbers actually placed in juxtaposition to those which, in our law of cell-genesis, would be their parents,—that is, 4 and 5 will be placed at the base of 1 and 2; 6, 7, and 8, at the base of 1, 2, 3; etc. Hence, he says, the conception of numerical genesis fulfils the geometrical conditions required, and ought to be taken into account in any theory of the organic law of vegetable growth.

Dr M'Cosh is disposed to think that the whole leafage coming out at one place in the stem corresponds to the whole plant, and the venation of each single leaf corresponds to the ramification of a branch. He also believes that there is a correspondence between the angle at which the branch goes off, and that at which the lateral veins go off. In most plants with woody structure the angle of both veins and branch ranges between 45° and 60°. In the greater number of herbaceous plants the angle varies from 25° to 45°. But both in trees and herbaceous plants there are angles so acute as 10° or 15°, and so obtuse as 70° or 75°. There is also a correspondence between the curve of the vein and the curve of the corresponding branches.

The leaf, after performing its functions, dies, and either falls off at once, leaving a scar, or remains for a certain time attached to the plant. In the case of lilies and hyacinths the leaves decay gradually, and remain for a long time as withered unsightly appendages. Provision is made for the fall of the leaf. Long before this a plane of separation begins to form at the base of the leaf-stalk, and it reaches its full development just at the time when the leaf ought to fall. A scar is left at the point of the stem where the leaf was attached. These scars give characters to plants, both in a living and fossil state, and deserve careful study. Dr Fleming divides trees, according to the duration of their leaves, into three classes:—1. Those in which the leaves cease to perform their functions when the bud is complete. 2. Those in which the leaves continue to perform their functions until new ones appear the following season. 3. Those in which the leaves continue to perform their functions for several years. The leaves of the first class are deciduous, and they seem to be connected with the ripening of the bud. When this takes place, these leaves change their colour and perish. This may be seen in willows. Leaves of the second class are annual. They continue till new leaves are produced, and are cast off in the order of their development. In evergreen trees and shrubs the leaves of one season continue their functions until those of the next season are produced. The leaves of the third class are persistent. Their duration does not seem to be regulated by the perfection of the bud, nor by the development of new leaves. They continue their functions for several years. This is the case with ordinary evergreen firs. The leaves of the Chilian Pine (*Araucaria imbricata*) seem to be remarkably persistent.

The fall and decay of leaves are brought forward in Scripture as emblems of man's passing existence on earth. "We all do fade as a leaf," says Isaiah (lxiv. 6). As in the case of the leaf there is a preparation going on for this fading. We carry about with us the elements of dissolution, and even in the midst of life changes are going on which point to the termination of existence. In the Bible a contrast is made between the wicked and the righteous by reference to the leaf. Thus transgressors and sinners "shall be as an oak whose leaf fadeth" (Isa. i. 30); and of the rebellious house of Israel it is said,—"It shall wither in all the leaves of her spring" (Ezek. xvii. 9); while on the other hand the Psalmist says of the godly man,—"His leaf also shall not wither" (Ps. i. 3).

> "Like leaves on trees the race of man is found,
> Now green in youth, now withering on the ground;
> Another race the following spring supplies;
> They fall successive, and successive rise;
> So generations in their course decay,
> So flourish these, when those are passed away."

How exquisite is the structure of a single leaf, with its delicate cells and vessels, its coloured particles, beauteous even in decay, its pores, its hairs, which sometimes display a continuous circulation of fluids, as seen in the nettle, its sensitive movements, its air cavities when required for floating, and its pitchers to carry fluids for nourishment. How wonderful to think that a feeble leaf fluttering in the breeze is not an isolated object in creation, but connected by the closest ties with the earth, the atmosphere, and the sun itself. All must conspire to carry on God's work on earth. Great and small are alike to Him who despiseth not the day of small things (Zech. iv. 10), and at the same time measures the waters in the hollow of His hand, and metes out the heaven with the span, and comprehends the dust of the earth in a measure, and weighs the mountains in scales, and the hills in a balance (Isa. xl. 12).

It has been well said,—"Gather a single blade of grass, and examine for a minute, quietly, its narrow sword-shaped strip of fluted green. Nothing, as it seems, there of notable goodness or beauty. A very little strength, and a very little tallness, and a few delicate long lines meeting in a point—not a perfect point neither, but blunt and unfinished—by no means a creditable or apparently much cared-for example of nature's workmanship; made, as it seems, only to be trodden on to-day, and to-morrow to be cast into the oven; and a little pale and hollow stalk, feeble and flaccid, leading down to the dull brown fibres of roots. And yet, think of it well, and judge whether of all the gorgeous flowers that beam in summer air, and of all strong and goodly trees, pleasant to the eyes or good for food—stately palm and pine, strong ash and oak, scented citron, burdened vine—there be any by man so deeply loved, by God so highly graced, as that narrow point of feeble grass. It seems to me not to have been without peculiar significance, that our Lord, when about to work that miracle, which, of all that He showed, appears to have been felt by the multitude as most impressive—the miracle of the loaves—commanded the people to sit down by companies 'upon the green grass.' He was about to feed them with the principal produce of the earth and the sea, the simplest representations of the food of mankind. He gave them the *seed* of the herb; He bade them sit down upon the herb itself, which was as great a gift, in its fitness for their joy and rest, as its perfect fruit for their sustenance; thus, in this single order and act, when rightly understood, indicating for evermore how the Creator had entrusted the comfort, the consolation, and sustenance of man to the simplest and most despised of all the leafy families of the earth. And well does it fulfil its mission. Consider what we owe merely to the meadow grass, to the covering of the dark ground by that glorious enamel, by the companies of those soft, and countless, and peaceful spears. The fields! Follow but forth for a little time the thoughts of all that we ought to recognise in those words. All spring and summer is in them—the walks by silent, scented paths—the rests in noonday heat—the joy of herds and flocks—the power of all shepherd life and meditation—the sunlight upon the world, falling in emerald streaks, and falling in soft blue shadows, where else it would have struck upon the dark mould or scorching dust—pastures beside the pacing brooks—soft banks and knolls of lowly hills—thymy slopes of down overlooked by the blue line of lifted sea—crisp lawns all dim with early dew, or smooth in evening warmth of barred sunshine, dinted by happy feet, and softening in their fall the sound of loving voices: all these are summed up in those simple words—the fields—and these are not all. We may not measure to the full the depth of this heavenly gift in our own land; though still, as we think of it longer, the infinite of that meadow sweetness, —Shakspere's peculiar joy,—would open on us more and more, yet we have it but in part. Go out, in the spring time, among the meadows that slope from the shores of the Swiss lakes to the roots of their lower mountains. There, mingled with their taller gentians and the white narcissus, the grass grows deep and free; and as you follow the winding mountain paths, beneath arching boughs all veiled and dim with blossom—paths that for ever droop and rise over the green banks and mounds sweeping down in scented undulation, steep to the blue water, studded here and there with new-mown heaps, filling all the air with fainter sweetness—look up towards the higher hills, where the waves of everlasting green roll silently into their long inlets among the shadows of the pines; and we may, perhaps, at last know the meaning of those quiet words of the 147th Psalm—'He maketh grass to grow upon the mountains.'" *

The parts of the plant which we have now

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* Ruskin's Modern Painters, vol. iii., p. 231.

considered—the root, stem, and leaves—constitute what are called the organs of nutrition or nourishment. Fluid matters are taken up by the cells of the roots from the soil, they are conveyed to the leaves, and there, under the influence of air and light, they are fitted for the purposes of plant-life, and for the production of various secretions, such as starch, gum, sugar, woody matter, gluten, oils, and resins. The nature of the soil has a material influence on the nourishment of the plant, and the process of manuring is conducted with the view of supplying certain substances which the plant requires for its vigorous growth, and which it cannot get from the particular soil in which it is placed. Some plants require ingredients which others do not need; and it is upon this principle that a certain rotation or change of crop in agriculture is adopted.

VIII. ON THE FLOWER AND ITS PARTS.

In the arrangement of the flowers on the floral axis, or what is called inflorescence, there are also evident alternate spiral arrangements. This is seen in various kinds of floral clusters, as in the hyacinth, London-pride, the fumitory (fig. 111), and the catkins of the hazel and willow. In these instances the numerous flower-buds are developed on the axis in an alternate manner. In some instances, as in borage, comfrey, and forget-me-not, the floral axis is evidently coiled up like a scorpion's tail (fig. 112).

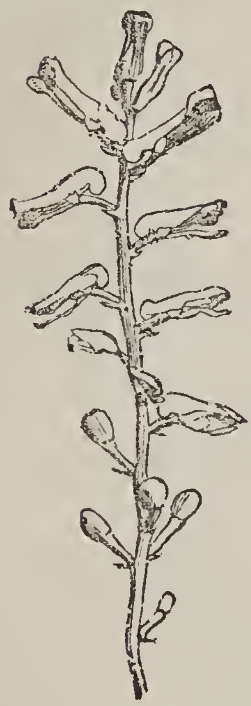
Fig. 111.

The flower and its parts are denominated the organs of reproduction, inasmuch as they are concerned in the production of seed which contains the embryo or young plant. Linnæus calls the flower the nuptial dress of the plant. The flower-bud, like a leaf-bud, proceeds from the point where a leaf joins the stem. This leaf is called the bract or flower-leaf (fig. 113, *b*). The parts of a flower are usually arranged in four series, or, as they are called, whorls.—1. The calyx. 2. The corolla. 3. The stamens. 4. The pistil. These parts are seen in figs. 114 and 115, in which *c* is the calyx, *p* the corolla, *s* the stamens, and *b* the pistil.

Fig. 111.—Peduncle or floral axis of Fumitory (*Fumaria officinalis*), bearing numerous flowers (multifloral). Each flower is attached to the rachis or floral axis by a short stalk called a pedicel, at the base of which a bractlet is produced. The length of this bractlet, as compared with the pedicel of the fruit, is useful in determining the species of fumitory.

In fig. 114 the different series of the flower are complete; in fig. 115 the calyx and corolla are

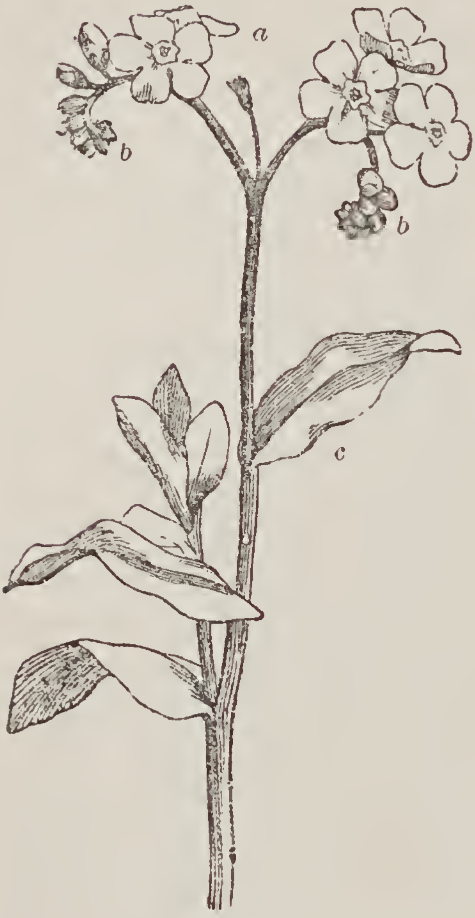

Fig. 112.

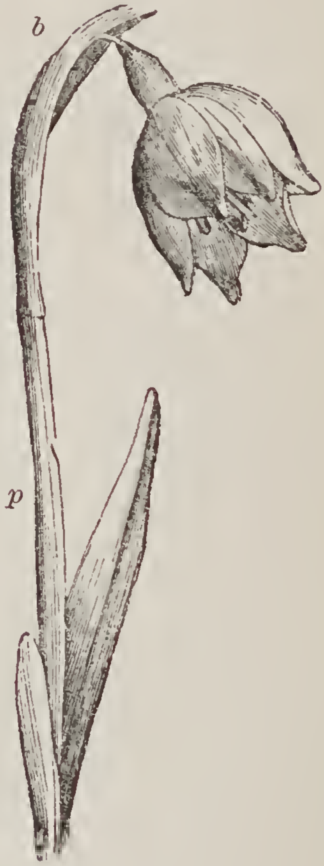

Fig. 113.

Fig. 112.—Helicoid cymes of Forget-me-not (*Myosostis palustris*). The floral axis arises from a leaf *c*, and ends in a solitary flower *a* From this axis proceed in a dichotomous manner helicoid or scorpioid cymes *b b*. Each flower is the termination of a separate axis, developed on one side only (unilateral or secund), and the whole inflorescence is curved like the shell of a snail, or the tail of a scorpion. The inflorescence is ebracteated—*i.e.*, the bractlets are suppressed.

Fig. 113.—Flower of spring Snow-flake (*Leucojum vernum*), supported on a peduncle *p*, called a scape, and coming out from a sheathing bract *b*. The flower is drooping and solitary, and the perianth is above the ovary.

removed. These are all considered as formed by leaves altered so as to suit the particular functions which each part performs. They sometimes appear in the form of true leaves without any marked modification. The inner two of the series are essentially connected with the production of seed, and are called essential organs (fig. 115). The outer two are protective and nutritive organs, and are called floral envelopes. When flowers become double, the stamens and pistil are more or less completely changed into parts resembling the outer series, and when the alteration is complete, no seed is produced. In the eyes of a florist,

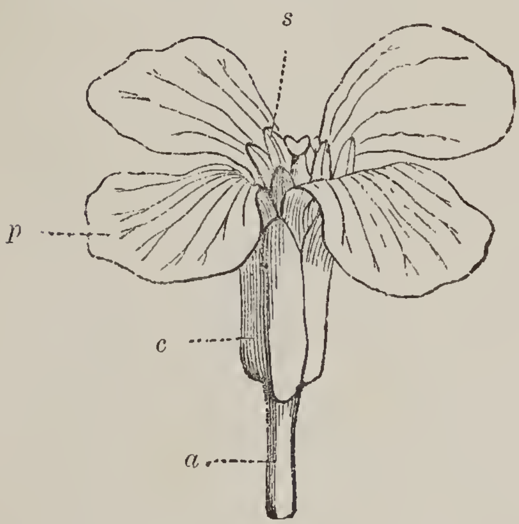

Fig. 114.

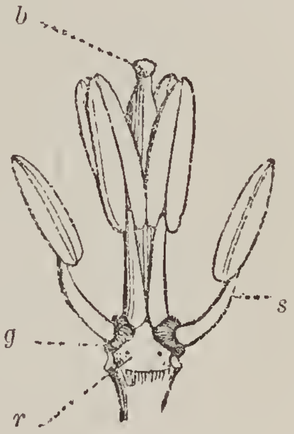

Fig. 115.

Fig. 114.—Flower of common Wallflower. *a* the flower-stalk, *c* the calyx, *p* the corolla, *s* the stamens.

Fig. 115.—Same flower with calyx and corolla removed. *s* stamen, *b* pistil—its upper part called the stigma, *r* the receptacle to which the parts of the flower are attached, *g* a small gland at the base of the stamen.

the more perfect the change, the finer is the flower; while the botanist looks upon such as monstrous, and imperfect as regards the function of reproduction. Double flowers, such as the camellia, often show well the spiral arrangement and alternation of the parts.

The parts of each series or whorl are arranged like leaves on the principle of alternation, and there is an evident symmetry as regards the number of the parts. The numbers which generally prevail in the flower are 5 and 3, or multiples of them. Thus, if a flower has 5 parts of the calyx, it has usually 5 of the corolla alternating with them; 5, 10, or 20, stamens; and 5, or some multiple of 5, in the parts of the pistil. So also with those flowers which have 3 parts in the calyx. In fig. 116 a diagram is given showing the alternation of the 5 parts of each whorl of the flower. The numbers 2 and 4 also occur in the parts of the flower, but they are by no means so frequent as those already mentioned. It is worthy of notice that flowers exhibiting 5 or 4, or multiples of these num-

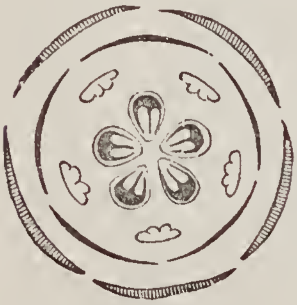

Fig. 116.

Fig. 116.—Diagram to show the arrangement of the parts of the flower. There are four whorls each consisting of five parts, which alternate with those next them.

bers in their whorls, usually belong to plants having two seed-lobes or cotyledons, and which, when they form permanent woody stems, exhibit distinct zones or circles, and have separable bark; while flowers having 3, or a multiple of 3, in their whorls, present only one seed-lobe, and when they form permanent woody stems, exhibit no distinct zones nor circles, and have no separable bark. The numbers 2 and 4, or multiples of them, are seen also in the parts of fructification of flowerless plants which have no seed-lobes, such as ferns, mosses, sea-weeds, etc. The processes which project from the urn-like cases of mosses are arranged in the series 4, 8, 12, 16, 32, 64, etc. The parts of fructification of scale-mosses (*Jungermanniæ*) are in fours, as also the germs of some sea-weeds. The numbers 5 and 4, and their multiples, prevail among dicotyledonous or exogenous plants; the number 3, and its multiples, occur among monocotyledonous or endogenous plants; while 2 and 4, and multiples of them, are met with among acotyledonous or acrogenous plants. In general, we may say, that the numbers 2, 3, and 5 prevail, with the multiples of 2, viz., 4 and 8. We have thus the leaf series 2, 3, 5, 8, as mentioned at page 145.

The parts forming the individual flower are arranged in a whorled manner, but in reality each whorl is a complete spiral cycle, the coloured leaves of which are placed closely together. Each separate whorl, or whorled cycle, alternates with that next to it. The arrangement of the parts of the flower of a plant does not always correspond with that observed in its leaves. Thus, in the Iris, the leaves of the creeping stem have a divergence of $\frac{1}{2}$, while in the flower the number is $\frac{2}{3}$. In Gentianella the leaves are in pairs at right angles to each other, while the floral leaves have a divergence of $\frac{3}{5}$. There is sometimes a difference also in the numbers expressing the divergence of the different whorls of the same flower.

There is frequently an interference with the law of symmetry in the flower by adhesion, by abortion, or by non-development of parts. The symmetry of a flower must be viewed to a certain degree independently of its regularity or irregularity of form. Symmetry has reference to number and arrangement of parts, regularity to size and appearance. A flower may be irregular in its form, and yet its parts may be symmetrical. Thus the common Veronica or speedwell (fig. 117) is irregular in its corolla, some parts being larger than others, yet *two* prevails in the flower. We often notice, however, that any cause which gives rise to want of symmetry also causes irregularity in form. By adhesion of parts there appears to be sometimes an interference with the proper number of parts in a whorl. Thus, in labiate or lipped plants, there are two lips of the corolla, and thus apparently only two parts, but in reality there are five, of which two adhere to form the upper lip, and three the lower (fig. 118). In Cypripedium or slipperwort, there are two in place of three parts of the calyx, in consequence of the adhesion of two. Non-development is a constant cause of want

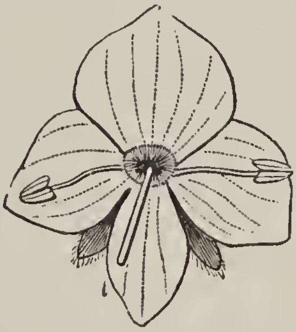

Fig. 117.

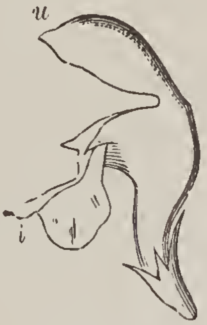

Fig. 118.

Fig. 117.—Irregular gamopetalous wheel-like corolla of Speedwell (*Veronica*). The irregularity consists in the different sizes of the lobes of the corolla, especially the lower lobe *l*, which is much smaller than the rest. There is an approach to a lipped corolla. The stamens are two, and the style one, so that the flower is Diandrous and Monogynous.

Fig. 118.—Irregular gamopetalous labiate corolla of the Dead-nettle (*Lamium album*). The upper lip *u* is composed of two petals united, the lower lip *l* of three. Between the two lips (labia) there is a gap (hiatus). The throat is the part where the tube and the labiate limb join. On account of arching of the upper lip this corolla is called ringent.

of symmetry. The corolla is sometimes absent, and then the flower has only one covering, and is called monochlamydeous (fig. 119). In such a case, the stamens are placed opposite to the parts of the whorl next them, in place of being alternate. At times a scale or scales occupy the place of calyx and corolla; and in other instances there is a complete want of both these parts (fig. 120). In a perfect flower stamens and pistil are present, but if these organs are in separate flowers, then we have a flower bearing stamens and no pistil, and hence called staminiferous, as in fig. 121; or a flower

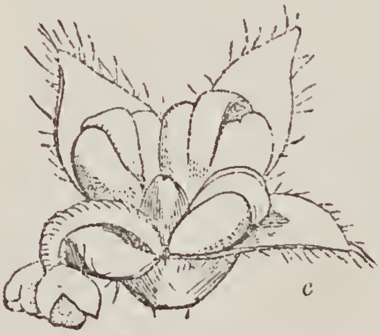

Fig. 119.

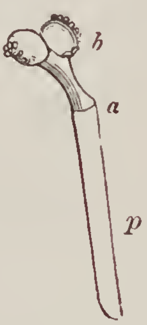

Fig. 120.

Fig. 119.—Flower of Pellitory (*Parietaria officinalis*). It contains four stamens, the filaments of which are incurved in the early state, and ultimately bend back with elastic force, so as to scatter the pollen *s*. There are four divisions of the perianth, or floral envelope *c*. The flower is monochlamydeous. The rudiment of a pistil is seen in the centre.

Fig. 120.—Flower of Euphorbia. The whole flower consists of a stamen *b*, supported on a peduncle *p*, to which it is united by an articulation at *a*. The flower is naked (achlamydeous). In some Euphorbias a perianth, or floral envelope, appears at the joint.

bearing a pistil and no stamens, and hence called pistilliferous (fig. 122).

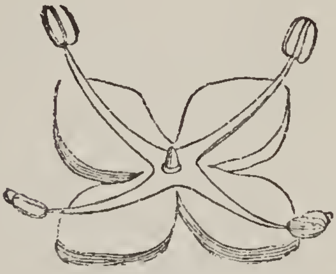

Fig. 121.

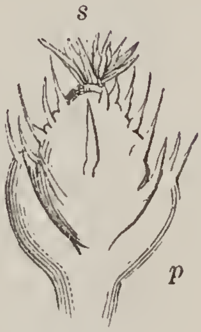

Fig. 122.

These varieties may be represented thus:—

1. Perfect flower, with five parts (pentamerous symmetry).

Calyx,	—		—		—		—		—	
Corolla,		—		—		—		—		—
Stamens,	—		—		—		—		—	
Pistil,		—		—		—		—		—

2. Pentamerous flower, having no corolla—Monochlamydeous.

Calyx,	—		—		—		—		—	
Corolla,		0		0		0		0		0
Stamens,	—		—		—		—		—	
Pistil,		—		—		—		—		—

Fig. 121.—Staminate, or staminiferous flower of Mulberry (*Morus nigra*), showing a four-partite calyx, and four stamens, with long filaments, and two-lobed anthers. The flower is monochlamydeous, from absence of the corolla, and the stamens are opposite the segments of the perianth on account of the suppression of the corolline whorl.

Fig. 122.—Pistillate or pistilliferous flower of the Nettle (*Urtica*). consisting of a two-leaved perigone, or floral envelope *p*, with a single pistil. The pistil consists of an ovary, and a sessile penicillate stigma *s*.

3. Pentamerous flower, with no floral envelope—Achlamydeous.

Calyx,	0		0		0		0		0	
Corolla,		0		0		0		0		0
Stamens,	—		—		—		—		—	
Pistil,		—		—		—		—		—

4. Pentamerous flower, having stamens only—Staminiferous; no envelopes nor pistil.

Calyx,	0		0		0		0		0	
Corolla,		0		0		0		0		0
Stamens,	—		—		—		—		—	
Pistil,		0		0		0		0		0

5. Pentamerous flower, with pistil only—Pistilliferous; no envelopes nor stamens.

Calyx,	0		0		0		0		0	
Corolla,		0		0		0		0		0
Stamens,	0		0		0		0		0	
Pistil,		—		—		—		—		—

In many such flowers the non-developed part required to complete the symmetry is present in an imperfect state. Often in pistilliferous flowers of the red Campion partially developed stamens are seen, while in the staminiferous flowers an imperfect pistil is detected. Some cases of partial development help to confirm the law of symmetry. Thus, in Gloxinia, the envelopes are in five parts, but there are only four stamens. On close examination, however, the fifth stamen is seen in the form of a small projecting point. That this is in reality an abortive stamen is proved by its becoming occasionally, under cultivation, perfect.

Along with this perfecting of the fifth stamen, the corolla also, in place of being irregular and inclined, becomes regular and erect. The symmetry of the pistil and fruit is often interfered with. Certain parts become abortive. and some increase at the expense of others, especially when they become fleshy. Thus, in the olive, the symmetry is dimerous or of two parts, but there is only one part in the ripe fruit. In the coco-nut the symmetry is trimerous, or represented by the number 3. In the ripe fruit, however, there is a single cavity and one seed, the other two being abortive. This abortion is proved by examining the shell of the coco-nut, in which there are three evident ridges indicating the three original parts.

By careful examination we can often account for apparent anomalies. Thus, in the fumitory there are two parts of the calyx, four of the corolla—that is, two and two, and six stamens. The latter, however, are found to be in reality four, inasmuch as two of them are formed each by a split stamen. It is represented thus:—

Calyx,		——		——	
Corolla,	1st row,		——		——
Do.,	2d row,	——		——	
Stamen,	1st row,		— —		— —
Do.,	2d row,	— —		— —	

The beautiful arrangements in plants are well fitted to fill our minds with wonder and admiration. Such co-ordinated facts as we have referred to, says M'Cosh, tend to raise up profound reflection in the truly philosophical mind, and open up glimpses to the religious mind of the deep things of God. Mathematical figures, more or less modified to suit special ends, make their appearance everywhere among the organs of the plant. The mathematical spiral regulates the arrangement of all its appendages, and numerical relations of a most interesting kind are detected. Where there is order there will of necessity be numerical relation. This idea of number seems to be as old as Pythagoras. Hence Professor Blackie in his "Lays and Legends" gives the following Dialogue:—

"But what rare wisdom did the Samian teach?"
"He saw the open mystery of number,
That makes the world a world, and doth redeem
All things from Chaos."
"Then let me hear the mystery of number!"
"Bring a flower!
Count me the petals."
"They are five."
"Then count the stamens, that like satellites
Keep circular guard around the central germ."
"I've told them twice. I think they number ten."
"Right; and twice five make ten; and so this flower

Divides by five. The Maker of the flower
Shaped the proportion ; this Pythagoras said."
"And have all flowers a number ?"
"Yes, all things
Are numbered, in a calculation far
Beyond the reach of Newton or Laplace."

"These studies," Agassiz remarks, "lead irresistibly to the conclusion that nature can only be the work of an intelligent Being,—of mind,—of an individual God. Everywhere there is a diversity among organised beings. Everywhere we find types among them that are identical. The facts, taken together, show that all organised beings have been ordered according to a plan. Thought is visible everywhere; in geological distribution, in organic structure and gradation. Everywhere there is an intellectual connection running through the whole. Were we not intellectual beings, allied by the nature of our intellect to the Maker of these, we could not read them. That we can trace the plan is proof of our mental affinity to the Being that planned it."

God's laws are perfect from beginning to end; nothing is left unprovided for. No contingency can arise to which these laws do not apply. Man has to vary and alter his plans according to circumstances. His best devices are constantly thwarted by the occurrence of some unexpected event. Not so with God. His omniscient eye surveys all from first to last, and nothing can interfere with His all-wise and all-provident laws. The mind is lost in the contemplation of such a wondrous complication, and yet such apparent simplicity. Truly it may be said that the works of the Lord are wonderful, and that the knowledge of them is too high for us, we cannot attain to it (Ps. cxxxix. 6). We see but a part of His doings; the thunder of His power who can comprehend? (Job xxvi. 14).

The arrangement of the flowers on the stem varies. Flower buds are produced either at the extremity of the main stalk, as in the gentianella (fig. 123), or laterally at the points where the leaves join the stems, as in the periwinkle and scarlet pimpernel (fig. 124). In the former case, a single flower terminates the floral axis, and any other flowers which may be afterwards developed are always further from the centre. This is shown in the figure of the clove-pink (fig. 125) where *a* is the central flower which opens first, *b* and *c* the second and third, which are still unexpanded. The opening of the flowers goes on thus further and further from the centre, or in a centrifugal manner. In the latter case, the axis goes on lengthening and producing flowers as it grows; the flowers arise from the points where the floral leaves or bractlets join the stem, and they expand from below upwards on a long axis, or from without inwards on a short one. Hence their expansion is centripetal, or towards the centre of the axis. The bractlets are sometimes very small and coloured, as in the hyacinth. Occasionally, in place of flower-buds, stalks bearing hairs are produced, as in *Rhus Cotinus* (fig. 126), which is, on that account, called the wig-tree, or the *arbre à perruque* of the French. In this case it is seen that the production of hairs indicates a degeneration of parts, or an abortive state of them.

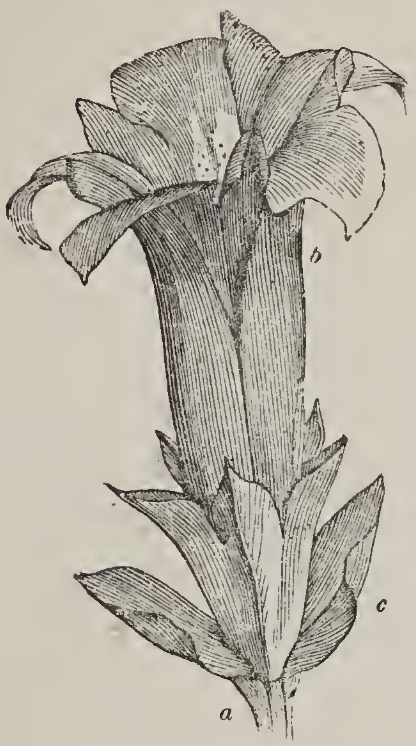

Fig. 123.

The flowering of plants takes place at differ-

Fig. 123.—Flowering stem of Gentianella (*Gentiana acaulis*). The plant produces a single flower, and it is called unifloral. The termination of the axis *a* bears two leaves or bracts *c*. The flower *b*, with its calyx and corolla, terminates the axis. This is the simplest form of definite inflorescence. If other axes are produced in such a case, they arise from the axil of the bracts *c*, and the flowers expand after the central one *b*, or in what is called a centrifugal manner. Each axis ends in a solitary flower.

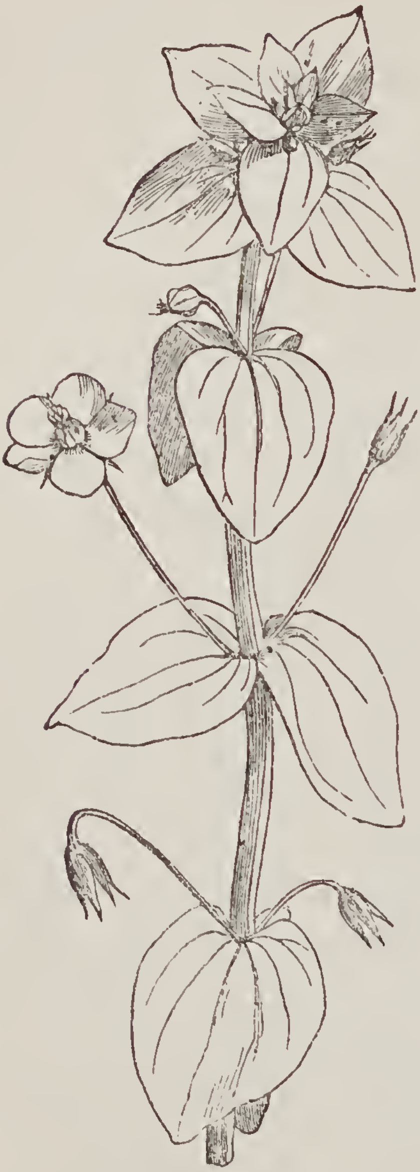

Fig. 124.

ent periods of the year, and thus a calendar of the season may be constructed. By observing the exact time when plants in the same garden flower in different years, an indication will be given of the nature of the season. The mezereon and snow-drop, hepatica and winter aconite, put forth their flowers in February in this country, the primrose and crocus in March, the cowslip and daffodil in April, the hawthorn in May, the great mass of plants in May and June, many in July and August, the ivy in September, the meadow-saffron and strawberry-tree in October and November, and the Christmas rose in December.

Fig. 124.—Flowering stem of the Scarlet Pimpernel or Poor-man's weather-glass (*Anagallis arvensis*). The floral stem or axis goes on

Some plants, as the daisy, produce their flowers throughout the whole season :—

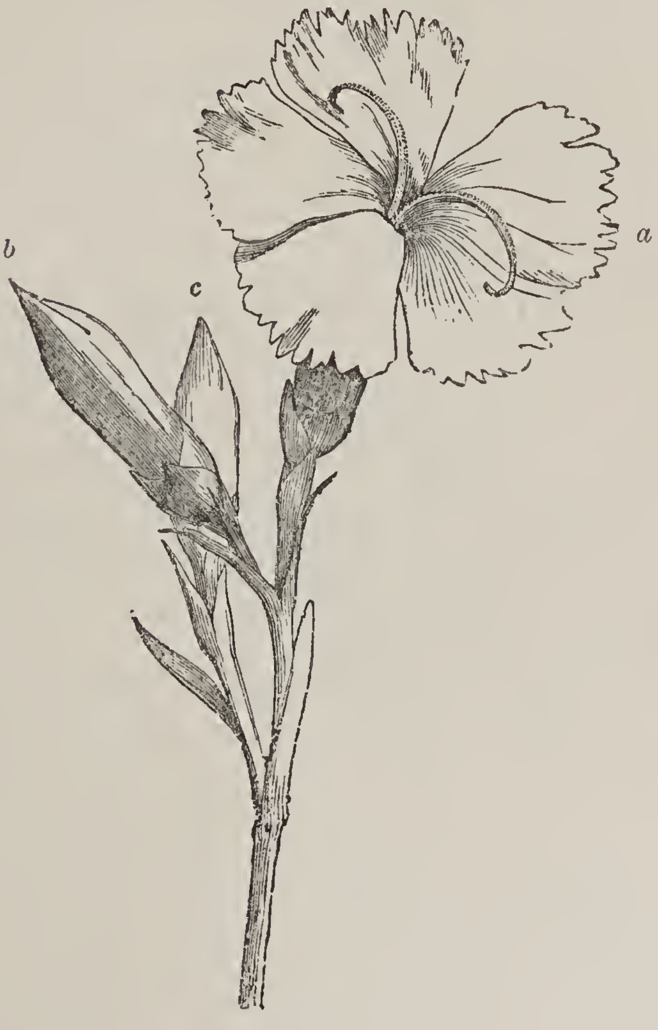

Fig. 125.

lengthening and producing flowers at the points where the leaves (called floral) join the axis. The lowest flowers expand first, and the others in succession upwards. This expansion is called centripetal, or towards the centre.

Fig. 125.—Flowering stalk of Clove-pink (*Dianthus Caryophyllus*). The flowers form a fascicle. The inflorescence is definite and centrifugal—the central flower expanding first, afterwards those at *b* and *c*. The plant is the origin of all the varieties of Carnation.

"There is a flower, a little flower,
With silver crest and golden eye,
That welcomes every changing hour,
And weathers every sky.

"It smiles upon the lap of May,
To sultry August spreads its charms,
Lights pale October on his way,
And twines December's arms."

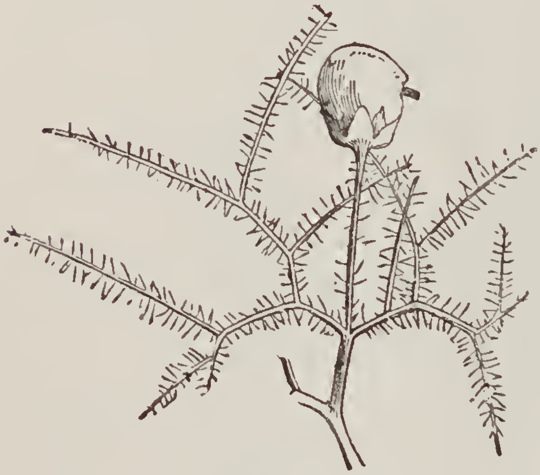

Fig. 126.

Flowers thus appear in orderly rotation. Thornton says:—"The snowdrop, foremost of the lovely train, dressed in its robe of innocency, breaks its way through the frozen soil long before the trees have ventured to unfold their leaves, and even while the icicles are pendent on our houses; next peeps out the crocus, but cautiously and with an air of timidity; nor is the sweet violet last in this shining embassy of the year, which, with all the embellishments that would grace a royal garden, condescends to line our hedges,

Fig. 126.—*Rhus Cotinus,* or the Wig-tree, so called on account of its flowering stalks bearing hairs in place of flowers. In the figure a solitary flower is shown; all the rest are abortive.

and to grow at the feet of briars. The polyanthus, after adorning the border with its sparkling beauties, gives place to the auricula, with its eye of crystal, and robe of the most glossy satin. Tulips then begin to raise themselves on their stately stalks, and adorn the parterre with the gayest colours." In succession appear the anemone, ranunculus, and carnation, to add fresh beauty to the scene. It is in vain to attempt to enumerate the varied flowery forms which succeed each other in the garden. There is an endless multiplicity in their character, yet an invariable order in their approaches. Every month, every week, has its peculiar ornaments; not servilely copying the works of its predecessor, but forming and executing some new design—so lavish is the fancy, yet so exact is the process of nature.

By observing the period of opening of the same flowers in the same exposure, year after year, we may draw important conclusions as to the nature of the seasons. The differences of seasons in this respect may be seen by the following register kept by the late Mr M'Nab, which shows the period of the first flowering of certain plants, in different years from 1852 to 1857, in the Edinburgh Botanic Garden :—

NAME.	1852.	1853.	1854.	1855.	1856.	1857.
Rhododendron atrovirens	Jan 14	Feb. 1	Feb. 18	Ap. 6	Feb. 16	Feb. 6
Herbaceous Heath	.. 24	Jan. 28	.. 20	Mar. 5	.. 15	.. 6
Snowdrop	.. 28	.. 24	Jan. 24	.. 2	.. 14	.. 8
Winter aconite	.. 31	Feb. 1	.. 26	.. 2	.. 14	.. 9
Hepaticas	.. 30	.. 2	.. 20	.. 7	.. 16	.. 13
Arabis albida	Feb. 18	Mar. 15	Feb. 15	Ap. 8	.. 24	.. 13
Sisyrinchium grandiflorum	.. 3	.. 3	.. 14	Mar. 5	.. 25	.. 14
Crocus susianus	.. 3	.. 8	.. 14	.. 5	.. 18	.. 15
Hazel	Jan. 25	.. 9	Mar. 10	.. 21	.. 15	.. 16
Rhododendron Nobleanum	.. 28	.. 22	.. 2	Ap. 13	Mar. 16	.. 18
Crocus vernus	Feb. 18	.. 15	Feb. 4	Mar. 6	Feb. 24	.. 19
Tussilago alba	.. 27	.. 1	.. 14	.. 15	.. 24	.. 20
Mezereon	Jan. 21	Feb. 1	.. 18	Ap. 6	.. 19	.. 23
Spring Snowflake	Feb. 21	Mar. 21	.. 15	Mar. 3	Mar. 1	.. 24
Aubrietia grandiflora	Mar. 18	Feb. 1	.. 17	Ap. 8	.. 1	.. 26
Nordmannia cordifolia	.. 10	Mar. 24	Mar. 1	.. 9	.. 8	.. 27
Doronicum caucasicum	.. 16	.. 26	.. 11	.. 11	.. 24	.. 27
Symplocarpus fœtidus	.. 20	.. 16	.. 3	Mar. 20	Feb. 26	.. 28
Tussilago nivea	Feb. 27	Ap. 1	.. 18	Ap. 14	Mar. 18	.. 28
Symphytum caucasicum	Feb. 2	Mar. 26	.. 11	.. 10	.. 12	Mar. 3
Pulmonaria angustifolia	Mar. 1	.. 20	.. 19	.. 20	.. 11	.. 8

The following plants have been recommended by the Vienna naturalists to be observed as to their periods of flowering, particularly the first fully-expanded blossoms :—

Acer platanoides, a kind of maple.
Horse-chestnut.
Barberry.
Catalpa syringifolia.
Colchicum.
Hazel.
Vernal Crocus.
Laburnum.
Mezereon.
Beech.
Cornus mascula.
Ash.
Crown Imperial.
Hepatica.
Barley, Wheat, and Rye.
Snowflake.
White Lily.

Bird-cherry.
Apple.
Cherry.
Gooseberry.
Red Currant.
Robinia.
Elder.
Lilac.
Vine.

Besides annual periods, some flowers exhibit diurnal periods of expansion and closing. On this principle Linnæus constructed what he called a floral clock, in which each hour was marked by the opening of some flower. The following is a specimen of such a horological calendar:—

Linnæus' Floral Clock:—

Ipomœa Nil,	3— 4	A.M.
Yellow Goatsbeard,	4— 5	,,
Wild Succory,	5	,,
Dandelion,	5— 6	,,
Spotted Cat's-Ear,	6	,,
Sow Thistle,	6— 7	,,
Water Lilies,	7	,,
Small Cape Marigold,	7	,,
Scarlet Pimpernel,	8	,,
Field Marigold.	9	,,
Sandworts,	9— 10	,,
Knotted Fig-marigold,	10— 11	,,
Common Star of Bethlehem (Dove's-dung of Scripture),	11	,,
Many Fig-marigolds,	12	,,
Afternoon Squill,	2	P.M.
Night-flowering Catchfly,	5— 6	,,
Evening Primrose,	6	,,
Marvel of Peru,	6— 7	,,
Night-flowering Cereus,	8— 9	,,

Shakspeare, in "Cymbeline," tells how

> "Winking Mary-buds begin
> To ope their golden eye."

Richter, in his remarks on Linnæus' floral clock, contrasts it with the periodical occupation of man at different hours of the day. "I believe," he says, "the flower-clock (*Horologium Floræ*), of Linnæus, in Upsal, whose wheels are the sun and earth, and whose index-figures are flowers, of which one always awakens and opens later than another, was what secretly suggested my conception of the human clock. I formerly occupied two chambers in Scheeraw, in the middle of the market-place: from the front room I overlook the whole market-place and the royal buildings, and from the back one the botanical garden. Whoever now dwells in these two rooms possesses an excellent harmony, arranged to his hand, between the flower-clock in the garden and the human clock in the market-place. At three o'clock in the morning the yellow meadow goatsbeard opens; and brides awake, and the stable-boy begins to rattle and feed the horses beneath the lodger. At four o'clock the little hawkweed awakes, choristers going to the Cathedral, who are clocks with chimes, and the bakers. At five, kitchen-maids, dairymaids, and butter-cups awake. At six, the sow-thistle and cocks. At seven o'clock, many of the ladies'-maids are awake in the palace, the chicory in my botanical garden, and some tradesmen. At eight o'clock, all the colleges awake, and the little yellow mouse-ear. At nine o'clock, the female nobility already begin to stir; the marigold; and even many young ladies, who have come from the country on a visit, begin to look out of their windows. Between ten and eleven o'clock, the Court ladies and the whole staff of lords of the bed-chamber, the green colewort and the alpine dandelion, and the reader of the princess, rouse themselves out of their morning sleep; and the whole palace, considering that the morning sun gleams so brightly to-day from the lofty sky through the coloured silk curtains, curtails a little of its slumber. At twelve o'clock the prince, at one his wife and the carnation, have their eyes open in their flower-vase. What awakes late in the afternoon at four o'clock is only the red hawk-weed, and the night-watchman as cuckoo-clock, and these two only tell the time as evening-clocks and moon-clocks. I could never know when it was two o'clock, because at that time, together with a thousand other stout gentlemen, and with the yellow mouse-ear, I always fell asleep; but at three o'clock in the afternoon, and at three in the morning, I awoke as regularly as though I was a repeater. Thus we mortals may be a flower-clock for higher beings, when our flower-leaves close upon our last bed ; or sand-clocks, when the sand of our life is so run down that it is renewed in the other world; or picture-clocks, because, when our death-bell here below strikes and rings, our image steps forth from its case into the next world. On each event of the kind, when seventy years of human life have passed away, they may perhaps say, 'What! another hour already gone! How the time flies!'"

The closing of flowers also follows a periodical law. Most flowers close during darkness. Some close even in daylight. Thus the salsafy shuts up its heads of flowers about mid-day, and the chicory about four in the afternoon. Many flowers are affected by the nature of the day as regards moisture, dryness, cloudiness, or clearness. In cloudy and rainy weather, the flowers of the scarlet or "pink-eyed pimpernel," called poor man's weather-glass (fig. 124, p. 180), remain closed. So also do the heads of flowers of the daisy, dandelion, and other composite plants. By this means the essential organs of the flower are protected from injury. Hogg, speaking of the effects of darkness on flowers, says,—

> "When the blewart[*] bears a pearl,
> And the daisy turns a pea;
> And the bonnie lucken gowan,
> Has fauldit up her e'e."

The direction of the flowers of some plants seems to be influenced by the sun's rays; and the name girasole or sun-flower, was given from an impression that the heads of flowers inclined towards the part of the heavens where the sun was shining. This does not, however, appear to be the case with the sun-flower as grown in this country. One of the species of girasole is the plant called Jerusalem artichoke. The first part of the name is a corruption of girasole, and the latter is given from the taste of the roots being like that of the common artichoke. Lindley states, that in *Brownea grandiceps* the brilliant head of flowers appears on the side of the main stem among the leaves, which every evening rise up and lift themselves from the blossoms so as to expose the flowers to the dew. In the morning the flowers are uncovered, but as the day advances the leaves gradually droop and bend down over the flowers to guard them from the rays of the sun.[†]

---

[*] Germander Speedwell (*Veronica Chamædrys*).

[†] Bot. Mag. pl. 4839.

The diurnal periods in flowering are alluded to by the poet in the following lines:

> "In every copse and sheltered dell,
> Unveiled to the observant eye,
> Are faithful monitors who tell
> How pass the hours and seasons by.
>
> The green-robed children of the spring
> Will mark the periods as they pass,
> Mingle with leaves Time's feathered wing,
> And bind with flowers his silent glass.
>
> See Hieracium's various tribes
> Of plumy fruit and radiant flowers;
> The course of time their blooms describe,
> And wake and sleep appointed hours.
>
> Broad o'er its imbricated cup
> The Goatsbeard spreads its purple rays,
> But shuts its cautious florets up,
> Retiring from the noontide blaze.
>
> On upland shores the shepherd marks
> The hour when, as the dial true,
> *Cichorium* to the towering lark
> Lifts her soft eyes, serenely blue.
>
> Thus, in each flower and simple bell
> That in our path betrodden lie,
> Are sweet remembrancers, who tell
> How fast the winged moments fly!"

The Calyx.—This is the outer covering or envelope of the flower. It is usually of a greenish hue like leaves. Sometimes, however, it is coloured, as in the fuchsia and Indian cress. It consists of a certain number of parts called sepals, which are either distinct from each other, when the calyx is polysepalous, as in the common butter-cup and wallflower (fig. 114, p. 167), or are united together more or less completely, when the calyx is gamosepalous, as in the harebell, gentianella, dead-nettle, and campion (fig. 127). The calyx is either regular, that is, has all its parts or sepals equal, as in the pimpernel (fig. 128); or it is irregular, that is, has its parts unequal, as in the dead-nettle (fig. 129). The calyx, in the case of the gooseberry, currant, cucumber, pear, apple, pomegranate, sun-flower (fig. 130), and many other plants, forms a

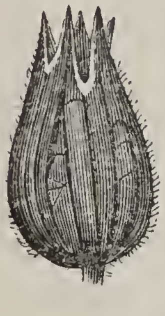

Fig. 127.

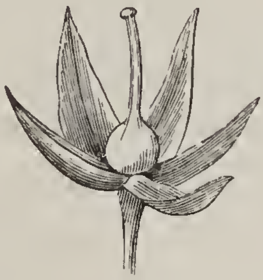

Fig. 128.

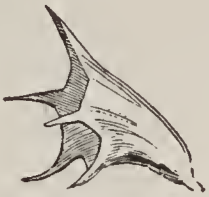

Fig. 129.

Fig. 127.—Gamosepalous five-toothed (quinque-dentate) calyx of Campion (*Lychnis*).

Fig. 128.—Gamosepalous five-partite (quinque-partite) calyx of Pimpernel (*Anagallis*), surrounding the pistil, which is composed of ovary, style, and stigma.

Fig. 129.—Bilabiate gamosepalous calyx of the Dead-nettle (*Lamium*). It is composed of two lips, the upper lip formed by three sepals, the lower by two. One of the upper sepals stands prominently out from the rest. The tube is formed by the united sepals, the free part of the calyx forming the limb, and the opening being the faux or throat.

covering of the fruit, and remains attached to it when ripe. In some plants the calyx is inconspicuous, and is reduced to a mere rim or slight projection, as in hemlock, and in certain rhododendrons, and in madder (fig. 131). In plants, such as the thistle and dandelion, which belong to the large division called composites, having numerous small flowers on a common head, the calyx is united to the fruit and appears at the upper end of it in the form of hairs or pappus (fig. 132). This is a degeneration of the calyx, which is made subservient to the scattering of the seed (fig. 133), and in the case of thistles is the means of diffusing extensively these noxious weeds.

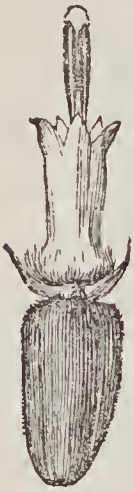
Fig. 130.

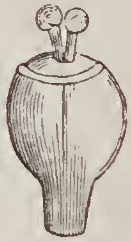
Fig. 131.

The order of composites, to which the thistle belongs, is the largest and most generally diffused of all known tribes of plants. There are now as many species belonging to the order, as there were known plants in the whole

Fig. 130.—One of the central flowers of the Sun-flower (*Helianthus*). The corolla is gamopetalous, five-toothed at the apex, the calyx is adherent to the fruit, and the limb of the calyx appears above the fruit in the form of a membrane, with pointed projections. The calyx is called superior, because its free portion is above the fruit. Extending beyond the flower are seen the stamens and pistil.

Fig. 131.—Calyx of Madder (*Rubia*), adherent to the pistil, its limb appearing in the form of a rim. The calyx is called obsolete.

world in the time of Linnæus, and most of them have the hairy calyx. Thistles themselves are generally distributed. Many species

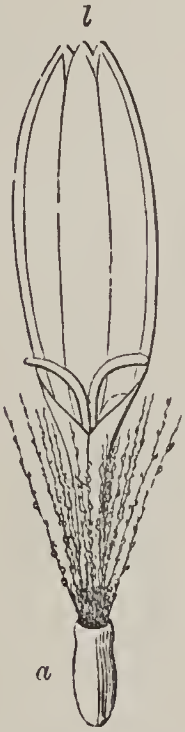

Fig. 132.

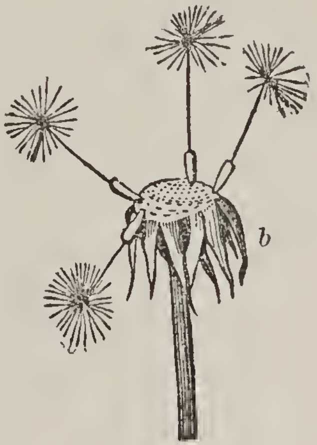

Fig. 133.

have been noticed by travellers in Syria and Palestine. Hasselquist, during a short visit to Judea, observed from eight to ten different

Fig. 132.—Irregular gamopetalous ligulate flower of Ragwort (*Senecio*). It is a tubular floret, split down on one side, with the united petals forming a strap-like projection *l*. The lines on the flat portion indicate the divisions of the five petals. From the tubular portion below, the bifid style projects slightly. The fruit (achænium), *a* is surmounted by pilose pappus, which is the metamorphosed calycine limb.

Fig. 133.—Receptacle or part of the Dandelion on which the flowers are placed. It is represented in the dry state when the plant is in fruit, and the leaves surrounding the head of flowers are turned back so as to allow the fruit to be easily scattered by the wind. The fruit is seen with the calyx attached and appearing above in the form of hairs or pappus.

species on the road from Jerusalem to Rama, and one on Mount Tabor. Thistles, and plants allied to them, such as the artichoke (*Cynara Scolymus*), now cover spots where formerly culture extended. Thus the prediction of Hosea is fulfilled, "The thorn and the thistle shall come up on their altars." The injury which thistles, and plants like them, cause to fields is very great, owing to the mode in which the fruit is scattered by the winds, and this altered hairy calyx is the means employed for doing so. May we not see in this the curse of thistles (Gen. iii. 18)? The calyx is not developed as in other plants, but is abortive,—blighted, as it were, and changed into hairs, which, as already shown (fig. 126, p. 182), indicate degeneration. Thus thistles add to the sweat and toil of man in the cultivation of the soil. It was the soil that was cursed by God (Gen. iii. 17), and to it we must trace the state of the vegetation. What it is in the soil which gives rise to all the degeneration in vegetable productions, and the arrestment in development, we know not. To keep up its fertility, man requires to labour constantly. The whole system of agriculture shows that materials require to be supplied, and that no soil will continue to produce good crops fit for food without the addition of manure. It may be that the sources whence fertility arises, whence the ammonia and other substances essential for plant-growth are derived, may have been so closed up, and so changed, as to be no longer available for the purposes of man. Even in the very deteriorations and degenerations of creation we see beauty; what then must it have been when God pronounced it good? In the present earth, there are abundant indications of the curse; but we are enabled to look forward to its removal, when there shall be a new earth as well as a new heaven, wherein dwelleth righteousness (Isa. lxv. 17, lxvi. 22; Rev. xxi. 1), when all will be complete and perfect, when the earth shall yield her increase, and God, even our own God, shall give us His blessing (Ps. lxvii. 6).

The Corolla.—This is, generally speaking, the showy part of the plant, in which the gay colours of the flower reside. It is sometimes wanting, as in nettles, willows, and catkin-bearing trees. When present, it consists of a number of leaves called petals, which are either distinct from each other, when the corolla is polypetalous, as in the buttercup, wallflower, cinquefoil, rose, and stonecrop (fig. 134), or united together in various ways, when it is gamopetalous, as in the gentian, foxglove, frogsmouth, dead-nettle, and harebell (fig. 135). A corolla is called regular when its parts or petals are of equal size, as in the strawberry (fig. 136); and it is irregular when the petals are of unequal size, as in speedwell and dead-nettle (figs. 117, 118, p. 171). Some irregular corollas present curious forms, resembling insects, such as butterflies, bees, spiders, etc.

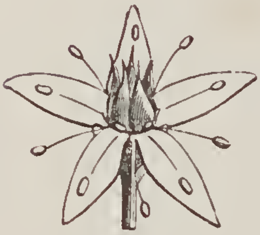

Fig. 134.

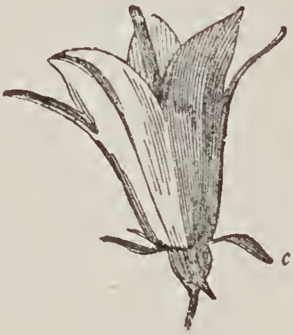

Fig. 135.

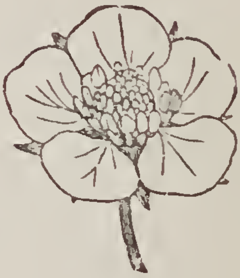

Fig. 136.

The perianths or flowers of orchids present most remarkable forms. Bateman, in his splendid work on the orchideous plants of Guatemala, makes the following remarks on them:—"Various resemblances to animal forms ap-

Fig. 134.— Polypetalous or Dialypetalous corolla of Biting Stonecrop (*Sedum acre*). It is composed of five separate petals, and hence is pentapetalous. There are ten stamens in two rows, and five carpels.

Fig. 135.—Regular gamopetalous bell-shaped (campanulate) corolla of Harebell (*Campanula rotundifolio*). It is composed of five petals united. The ovary is inferior, and is united to the calyx, *c*.

Fig. 136.—Rosaceous corolla of the Strawberry (*Fragaria vesca*), composed of five petals without claws. The points of the calyx are seen alternating with the white petals.

pear in the orchid flowers. Thus, flies are seen in *Ophrys muscifera*, bees in *O. apifera*, drones in *O. fucifera*, spiders in *O. aranifera*. The columns of many of the Catasetums, and other genera, make excellent grasshoppers. Mosquitoes are borne by *Trichoceros antennifer*, or *Flor de mosquito*, of the Peruvians; dragon-flies by *Renanthera arachnites;* moths by *Phalænopsis amabilis.* Insect-like antennæ are also conspicuous in the flowers of *Restrepia antennifera.* The butterfly-plant of Trinidad is the now well-known *Oncidium Papilio.* Swans are found in the species of *Cycnoches*, doves in *Peristeria elata*; pelicans in *Cypripedium irapœanum*, which from the great resemblance of its flowers to the bird of that name, is styled by the natives *Flor de pelicano.* The skins of the tiger and the leopard are rivalled by the petals of such plants as *Stanhopea tigrina*, *Bolbophyllum leopardinum*, etc. The *flos lyncea* of Hernandez (*Stanhopea Martiana*), is so called from its lynx-like eyes and teeth; *Dendrobium taurinum* has much of the bull about its face; and various *Catasceta*—*C. semiapertum* especially—grin like the ugliest monkey. *Aceras anthropophora*, the man-orchis, is a well-known plant. Even extinct animals do not always escape; a geologist would instantly recognise the head of a Dinotherium in the flowers of *Masdevallia infracta*. *Pleurothallis ophiocephala* has a strong resemblance to a serpent's head, and *Pholidota imbricata* an equally strong resemblance to a rattlesnake's tail. Lizards occur in *Pleurothallis saurocephala* and *Epidendrum lacertinum*, and frogs in *Epidendrum raniferum*."

The petals are composed of a congeries of minute cells, each containing colouring matter, and delicate spirals interspersed, all being covered by a thin epidermal coat or skin. The coloured cells are distinct from one another, and thus a dark colour may be at one part and a light colour at another. One of the most beautiful objects under the microscope is the petal of a pelargonium. One way of preparing the petal is by immersing it in sulphuric ether for a few seconds, and then allowing the fluid to evaporate. Another mode is simply to dry the petal, immerse it for an hour or two in spirit of turpentine, and then put it up in new Canada balsam. Another way is to peel off the skin from the petal by making an incision in its prominent end, and then tearing it forward with the forceps. Arrange this on a slip of glass, and allow it to dry. When dry it adheres to the glass. Place on it a little Canada balsam diluted with turpentine, and boil it for an instant over a spirit lamp. This blisters it, but does not remove the colour. Cover it then with a thin slip of glass. On looking with the microscope, you observe beautiful hexagons, the boundaries between which are ornamented with several inflected loops in the sides of the cells, and in the centre of each marking is a star-like figure. If the piece of skin has been torn across one of the dark streaks of the petal, we can see the colouring matter in separate cells.

The colours of flowers are arranged in two marked series, the yellow and the blue. A plant belonging to the yellow series may exhibit all the tints of white, yellow, and red, but it does not appear to have the power of becoming blue. So also with a plant of the blue series. It too may exhibit varying tints of white and red and blue, but generally refuses to become yellow. The tulip, the dahlia, and the rose belong to the yellow series; and while, by cultivation, they exhibit innumerable changes, yet they have not been made blue. The common harebell belongs to the blue series, and is not seen to assume the yellow. Such appears to be the general law, although there are no doubt some apparent exceptions, especially in cases (such as the pansy) where blue and yellow occur in the petals of the same flower. But it still remains to be proved that a petal truly yellow can be changed by the art of the gardener into blue.

Blue can pass into red by means of acids, and can present all the colours resulting from the mixture of blue and red. Yellow is capable of reddening by oxygenation (*i.e.*, by the action of oxygen), and also by acids (as in the yellowish juice of some cells of the leaves of red cabbage), and hence yellow flowers may pass to red, and also present all the shades intervening between these colours. The red colour, however, of the blue and yellow series is not the same. That of the yellow series seems to be less common in leaves than in flowers; that of the blue series is the reverse. The two kinds of red (one belonging to the blue and the other to the yellow) are sometimes united in the same flower, which may thus present every imaginable variety of colour. This, however, is a very rare occurrence.

It has been observed that the colours which unite in forming the white light of the sun's ray may be reduced to three—red, yellow, and blue. These have been called primary colours.

Each of these primaries requires the other two in order to form a white colour. Hence the latter are called complementary, being necessary to make up the complement of colours in white light. Thus, red has green (made up of blue and yellow) for its complementary colouring; blue has orange (made up of yellow and red); and yellow has purple (made up of red and blue).

Dr Dickie has devoted attention to the colour of flowers, whether regular or irregular, and the following are the results of his observations:—"The primary colours, as red, yellow, and blue, which by their union in the sunbeam produce white light, are generally present in some part or other of the plant. In regular corollas the colour is uniformly distributed, whatever be the number of colours present. That is, the pieces of the corolla being all alike in size and form, have each an equal proportion of colour. In the primrose there is one colour, uniformly distributed. In the Chinese primrose there are two, the eye or centre being yellow, and the margin showing the complementary colour purple. Each of the parts, in the latter instance, has an equal proportion of yellow and purple. Again, irregularity of corolla is associated with an irregular distribution of colour. An odd lobe or petal of such a corolla is often as much varied in colour as it is in form and size. This difference is seen in some pea-blossomed flowers, in the lip of some labiate plants as galeopsis, and in the violet. In composite plants, such as asters, daisies, etc., there are two forms of corolla, one in the centre, regular and of one kind of colour, and the other in the margin or ray, irregular and differently coloured." *

Chevreul has made some interesting observations on the simultaneous contrast of colours. He remarked, that when two coloured objects, say red and green, are placed side by side, or so near to each other as to be seen together, the quality and intensity of the separate colours do not appear the same as when looked at separately. Thus the same red object will have a different hue if seen side by side with a green, with a yellow, and with a blue object, and these colours will in their turn be modified to the eye by their juxtaposition with red. A similar statement may be made as regards shades or tints of the same colour when placed together.

Contrast of colour occurs according to the principle, that every colour adds its complemen-

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* M'Cosh and Dickie on Typical Forms.

tary to the colours placed near or beside it. Thus, red causes the colours near it to appear as if its complementary green were added to them. Green tints them with red; blue adds to other colours orange; yellow adds to them purple. The reason why complementary colours, such as red and green, in flowers give pleasure is because each exalts the other, so that the red makes green greener, and green makes red redder, than either would appear alone. The eye is gratified with the full colours in these cases, not in virtue of some vague recognition of complementary colours, but because by no other arrangement can two colours be made to show so fully and richly.*

How exquisitely are the colours of flowers diversified, and with what a masterly skill are their varied hues arranged! Whether blended or separated, as Thornton remarks, they are evidently under the control of a taste which never falls short of the perfection of elegance. The Creator has added to them the charms of an endless novelty, to please the eye and contribute to the enjoyment of man.

> "Not a flower
> But shows some touch, in freckle, streak, or stain,
> Of His unrivalled pencil."

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* Edinburgh New Philosophical Journal, New Series, vol. i. p. 168.

When with microscopic eye we examine the flower of the lily of the field, and observe the beautiful structure in which the colours are developed, and "see how nature paints her colours," how truly may we exclaim, "Solomon in all his glory was not arrayed like one of these" (Matt. vi. 29; Luke xii. 27). The tints of his kingly robes might have been as bright and varied; but where were the cells and the delicate tissues of the flower?

"Bowing adorers of the gale,
Ye cowslips delicately pale,
Upraise your loaded stems;
Unfold your cups in splendour, speak!
Who decked you with that ruddy streak,
And gilt your golden gems?

"Violets, sweet tenants of the shade,
In purple's richest pride arrayed,
Your errand here fulfil;
Go bid the artist's simple stain
Your lustre imitate, in vain,
And match your Maker's skill.

"Daisies, ye flowers of lowly birth,
Embroiderers of the carpet earth,
That stud the velvet sod;
Open to spring's refreshing air,
In sweetest smiling bloom declare
Your Maker, and my God."

The fragrance and odours of flowers reside generally in the petals. These are owing to volatile matters which are not easily detected, the subtile particles of which are diffused through the air in a way which eludes the researches of man. Some colours are associated frequently with certain kinds of odours. Thus dark brown flowers, such as those of stapelias (fig. 137), have usually very fetid and disagreeable odours. Hence they are called carrion flowers, and are noted for attracting flies, which probably serve an important purpose, as will be afterwards shown, in the production of the seed. Sunshine has in general a marked effect in developing the odours of flowers. Hence in those climates where the sun displays all its brightness, the air is perfumed with fragrant odours. In many cases, alternate showers and sunshine bring out particular odours, and in some instances the perfumes are intermittent, and are only given out during the night. Moore speaks of the *Nyctanthes arbor tristis* as

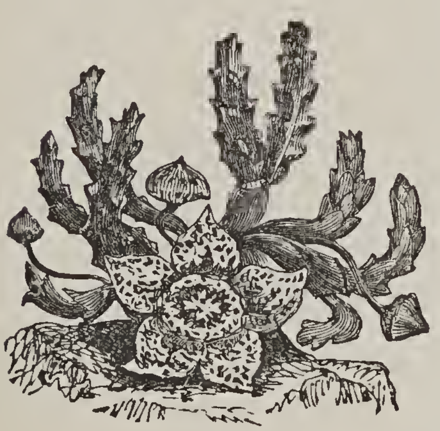

Fig. 137.

Fig. 137.—Flower of Stapelia, having a very fetid odour, and hence called carrion flower.

"The timid jasmine buds that keep
Their odour to themselves all day;
But when the sunlight dies away,
Let the delicious secret out
To every breeze that roams about."

The plants called *tristes*, or sad, by Linnæus, including the night-smelling stock and Pelargonium, are of this nature, and so are several species of night-flowering Cereus.* The odour of the latter plants seem to be in a certain measure intermittent, and comes out in puffs every half-hour from about eight in the evening till midnight. Morren states, that on one occasion the flower of *Cereus grandiflorus* began to expand at six o'clock in the evening, when the first fragrance was perceptible in the hothouse. A quarter of an hour afterwards the first puff of odour took place, after a rapid motion of the calyx; at twenty-three minutes past six there was another powerful emanation of fragrance; by thirty-five minutes past six the flower was completely open; at a quarter to seven the odour of the calyx was the strongest, but modified by the petals.

The exquisite perfumes of flowers are preserved in various ways by the art of the perfumer, either by being taken up by means of rectified spirit, or by means of oils and fats of various kinds. British India and Europe alone consume annually more than 150,000 gallons of perfumed spirits under various titles, such as Eau de Cologne, Essence of Lavender, Esprit de Rose, etc. A single perfumer of Grasse and Paris employs annually 80,000 lbs. of orange flowers, 60,000 lbs. of acacia buds, *i.e.*, flower heads of *Acacia Farnesiana*, 54,000 lbs. of rose petals, 32,000 lbs. of jasmine flowers, 32,000 lbs. of violets, 20,000 lbs. of tuberose 16,000 lbs. of lilac, and still larger quantities of rosemary, mint, citron, thyme, etc. Eighty thousand persons are employed directly or indirectly in the south of France in extracting their odours; and tracts of flower-farms exist in Turkey more extensive than the whole of Yorkshire.*

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* See Dr Fleming's work on the "Curve of Temperature," p. 53.

The enjoyment which man derives from the odour of flowers is used in Scripture to signify God's approbation of His people,—the plants of His garden. In the Pentateuch there are constant references to the Lord smelling a sweet savour; and St Paul says of believers, "for we are to God a sweet savour of Christ," who "hath given Himself for us an offering and a sacrifice to God for a sweet smelling savour" (2 Cor. ii. 15; Eph. v. 2). Solomon alludes to the fragrance of the flowers of the garden when he says, "My spikenard sendeth forth the smell thereof;" and again, "Awake, O north wind; and come, thou south; blow upon my garden, that the spices thereof may flow out" (Cant. i. 12; iv. 16). Prayer accepted of God is represented as incense of sweet odour rising up to heaven: "The four living creatures and the four-and-twenty elders fell down before the Lamb, having every one of them harps and golden vials full of odours, which are the prayers of saints" (Rev. v. 8). And the Psalmist says, "Let my prayer be set forth before thee as incense" (Ps. cxli. 2).

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* Piesse, Art of Perfumery.

In certain flowers there have been observed movements of the petals. In some of the orchids the peculiar petal called the lip, moves in a hinge-like manner when irritated. Various species of Pterostylis and Bolbophyllum show movements in the labellum or lip. In *Calcana nigrita*, a Swan River orchid, the column is a boat-shaped box, the lid of which is formed by the lip. The latter is hinged on a claw, which reaches the middle of the column. When the flower opens the lip turns round within the column and falls back, so that, the flower being inverted, it stands fairly over the latter. The moment an insect touches its point, the lip makes a sudden revolution, brings the point to the bottom of the column, passing the anther in its way, and thus makes prisoner any insect that the box may contain. If an insect is caught, the lip remains shut, but if no insect is caught, it recovers its position.*

The Stamens.—These form the third series of parts in the flower (fig. 115, p. 167). In fig. 138 they are numerous, and surround the central pistil, which is longer than the stamens. Like the other parts of the flower, they are considered as a modification of leaves. In double flowers. they are converted into petals. They consist usually of two parts, a stalk or filament (fig. 139, *f*) supporting two small cellular bags at the top of it (fig. 139, *a*), which are called the

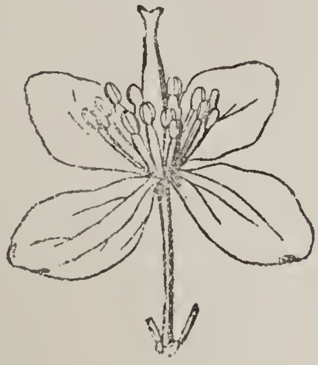

Fig. 138.

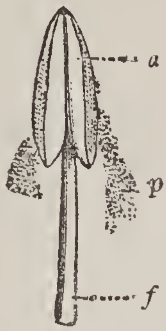

Fig. 139.

Fig. 138.—Flower of Celandine. The calyx has fallen off, the four petals are seen, numerous stamens and one pistil in the centre.

Fig. 139.—A stamen consisting of filament *f*, anther *a*, and pollen *p*, discharged from slits in the anther lobes.

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* Lindley's Vegetable Kingdom, p. 179.

anther lobes. The anther contains a powder (fig. 139, *p*), often of a yellow colour, called pollen, which is essential to the production of perfect seed in flowering plants. At a certain period of growth, this powder is discharged from the anther, which opens by means of slits (fig. 139), or of hinges, as in the barberry and laurel, or holes, as in the heath, rhododendron, and potato, to allow its escape. The anther has two coverings, the inner of which often contains elastic spirals, which seem to assist in the opening of the lobes. The pollen, or the dust of flowers, when examined by the microscope, presents multiplied forms. It must be applied to the pistil or central part of the flower, in order that the seed may be perfected.

The number of stamens bears a relation usually to the other parts of the flower. They are either equal to the number of parts in the calyx or corolla, or some multiple of them. When there is a want of correspondence as regards number, it will be found that this depends usually on something abnormal. Thus, in irregular lipped plants (fig. 118, p. 171), there are 5 parts of the calyx and 5 of the corolla, but frequently only 4 stamens, on account of one stamen being undeveloped. The stamens in such cases are usually of different lengths. The number of the stamens is taken into account in the Linnean or artificial system of classification; the Greek numerals being prefixed to the term *andria*, meaning stamen. The stamens, like the sepals and petals, may be either separate or united together. The union of the stamens may take place by means of their filaments or by their anthers.

Many beautiful arrangements are made for ensuring the proper application of the pollen to the upper part of the pistil. The agency of winds, of elasticity, of irritability, and of insects, is called into operation in different cases. In the common nettle, and in the pellitory of the wall, the stamens have elastic filaments, which are at first bent down, so as to be covered by the calyx; but when the pollen is ripe, the filaments jerk out, as seen in fig. 119, p. 172, and thus scatter the powder on the pistils, which occupy separate flowers. In the common barberry (fig. 140), the lower part of the filament is very irritable; and whenever it is touched, the stamen moves forward to the pistil. In the stylewort (*Stylidium*), as seen in fig. 141, the stamens and pistil are united in a common column which projects from the flower; this column is very irritable at the angle where it leaves the flower, and, when touched, it passes with a sudden jerk from one side to the other, and thus scatters the pollen. In the hazel, where the pollen is in one set of flowers (fig. 142, ♂) and the pistil in another (fig. 142, ♀), the leaves might interfere with the application of the pollen, and therefore they are not produced until it has been scattered. In the case of firs, which have their flowers arranged as in the hazel, stamens at one place and fruit-bearing cones (fig. 110, p. 153) at another, the evergreen leaves are very narrow,

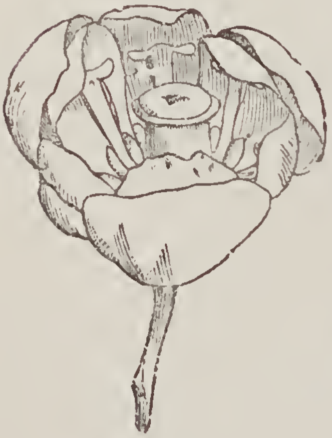


Fig. 140.

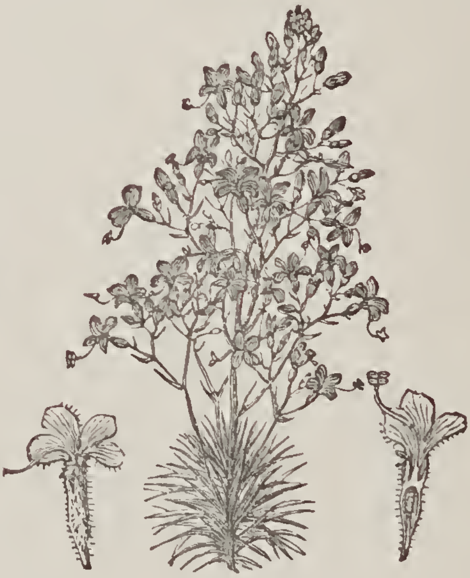


Fig. 141.

Fig. 140.—Flower of the Barberry (*Berberis vulgaris*), the stamens of which are irritable, and move towards the pistil when touched at their base. The irritability resembles that of the Sensitive plant, and is referred to turgescence in certain cells, and to contraction in others.

Fig. 141.—Stylewort of Australia (*Stylidium*), with two of the flowers separated, showing the irritable column composed of stamens and pistil united. This column, when the pollen is ripe, jerks from one side of the flower to another, and thus scatters the powder.

and the quantity of pollen produced is very great, so as to ensure its reaching the young cones. In America, and even in Scotland, the pollen from pine forests is sometimes carried to a great distance by winds, and falls in showers like sulphur. In the month of May, in this country, a visit to a forest of firs will show the large quantity of yellow powder which falls from the trees when shaken. In the case of cucumbers in a glass frame, where the wind cannot reach the flowers, the gardener takes the pollen from the one kind of flower and applies to the other, in order that he may get fruit. In willows, the stamen-bearing and pistil-bearing flowers are on separate trees. In fig. 143 is seen a collec-

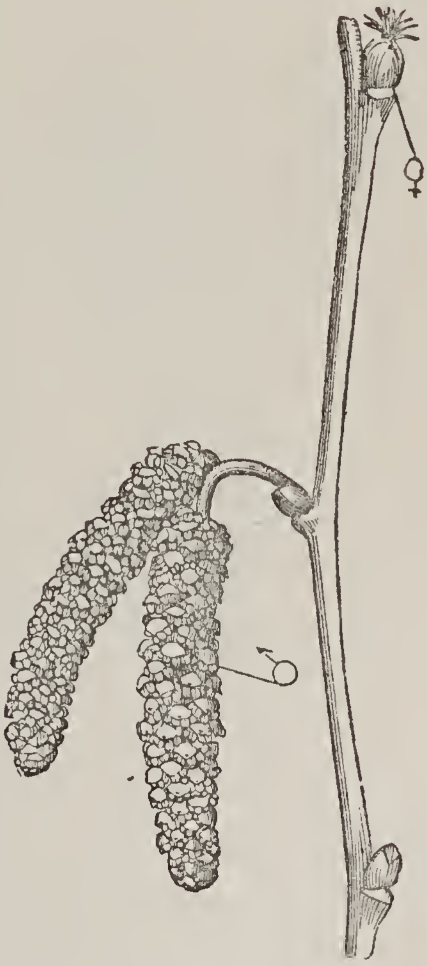


Fig. 142.

Fig. 142.—Hazel (*Corylus Avellana*), showing two kinds of flowers which are produced before the leaves. ♂ the catkins bearing stamens. ♀ the pistil-bearing flowers which produce nuts.

tion or catkin of flowers with stamens only, in fig. 144, another collection with pistils only. The two kinds of trees grow near each other, and the wind wafts the powder from the one to the other. In *Vallisneria spiralis* (fig. 26, p. 35), an aquatic plant, which grows in the mud of ditches in the south of Europe, the pollen of the stamen-bearing plant (fig. 26 *a*) at a certain period is detached from the mud and rises to the surface of the water, where it floats and ripens its pollen. Soon after this, the pistil-bearing

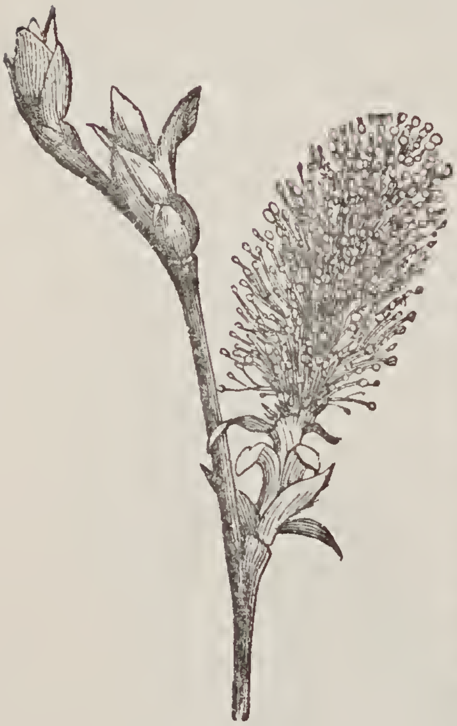


Fig. 143.

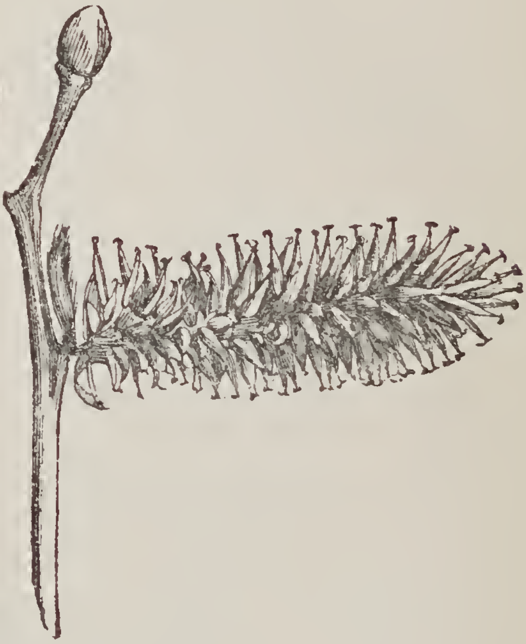


Fig. 144.

Fig. 143.—Willow, with a catkin or cluster of stamen-bearing flowers.
Fig. 144.—Willow, with a cluster of pistil-bearing flowers.

plant (fig. 26 *b*) which still remains growing in the mud, sends up a long spiral stalk, as seen in the figure, which bears the flower to the surface, where it expands. The pollen is then wafted on it by the wind, and the seed is perfected, and finally deposited in the mud.

Insects are often, in the arrangements of Providence, made the means of securing the production of seed. How often do we see the bees collecting the yellow powder of plants, and, while providing for the food of their young, aiding in dispersing the pollen. The honey-like matter secreted by flowers renders them attractive to insects. It is produced by an alteration in the starch, which occupies cells at the bottom of the flowers. In the common crown-imperial of the gardens there is a distinct depression at the base of each petal, in which the honey or nectar is secreted. In common buttercups, a small scale at the bottom of each of the yellow petals points out the seat of the sugar-like matter. The peculiar insect-like form of the flowers of orchids (figs. 145, 146), such as the bee orchis, the fly orchis, the spider orchis, the butterfly oncidium, seem to be connected with the attraction of insects to the flowers, in order to apply the pollen, which in these plants is singular, both as regards its situation and nature. In the birthwort (*Aristolochia*), the flower consists of a long tube (fig. 147) in a chamber, at the bottom of which the stamens and pistil are placed, completely shut out from the agency of winds. The

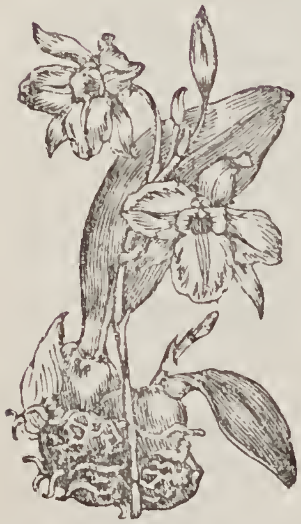


Fig. 145.

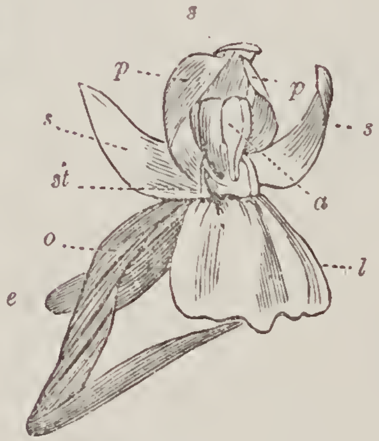


Fig. 146.

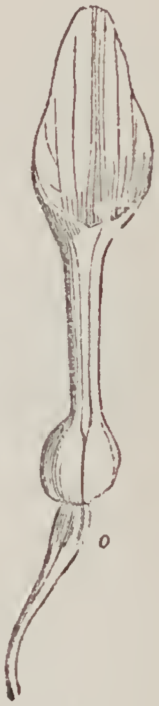


Fig. 147.

Fig. 145.—Orchideous Epiphyte, showing its peculiar flowers and pseudo-bulb.

Fig. 146.—Flower of an Orchid, consisting of three outer divisions of the perianth, *s s s*, three inner, *p p l*, the latter *l* being the labellum, which is placed below by the twisting of the ovary ; *e* the spur of the labellum ; *o*, the twisted ovary ; *st* the stigma ; *a*, the anther containing masses of pollen.

Fig. 147.—Flower of Birthwort (*Aristolochia Clematitis*) showing the long tube and the expanding upper part of the flower. The seed-vessel *o*, containing seed, is below the flower. The tube is lined with hairs which point downwards. An insect entering the flower easily passes the hairs, but in attempting to come out it is stopped.

position of the stamens and pistil is seen in fig. 148, where the floral envelope is removed. This plant is frequented, in its native country, by an insect which enters the tube easily and gets into the little chamber. On attempting to get out, it is prevented by a series of hairs in the tube, which all point downwards. It therefore moves about in the little cavity, and thus distributes the pollen on the pistil, soon after which the flower withers and the insect escapes. Such are a few of the provisions made by the Creator to secure the production of seed in the various tribes of plants with which the earth is clothed, and thus the "herb bearing seed" is found in all quarters of the globe.

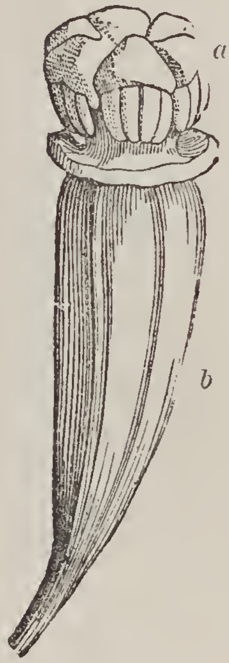


Fig. 148.

The Pistil.—This is the central part of the flower, and is composed of one or more folded leaves or *carpels.* It may consist of a single carpel, as in the pea and vetch (fig. 161, p. 224), or of several, either distinct from each other, as in the pæony and stonecrop (fig. 153, p. 219), or combined, as in the tulip and lily (fig. 154, p.

Fig. 148.—The stamens and pistil *a*, of Aristolochia, the former placed below the part of the latter called the stigma; *b* the fruit or seed-vessel.

219). In the double-flowering cherry, in which the stamens are changed into petals, the pistil appears in the form of a flat leaf, as represented in fig. 149, or of a folded leaf, as in fig. 150. The plant does not produce fruit, on account of the change which has taken place in the stamens and pistil. The parts of the pistil are seen in fig. 151. The rounded top *s* is the stigma, the stalk below *st* is the style, and the lower swollen portion *o* is the ovary, containing the cellular ovules which become seeds. These parts are better seen in fig. 152, which represents the

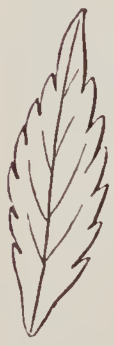


Fig. 149.

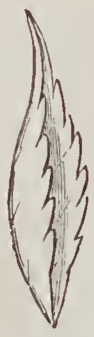


Fig. 150.

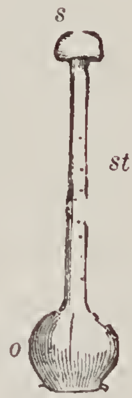


Fig. 151.

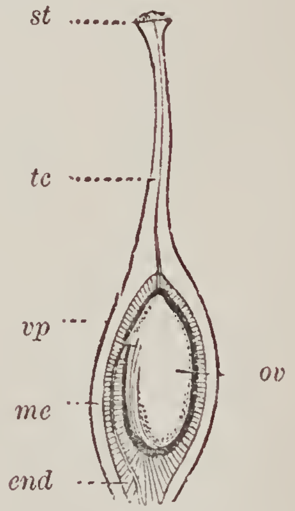


Fig. 152.

Figs. 149 and 150.—The pistil of the double-flowering cherry, composed of a leaf (*carpel*) either flat, as in 149, or folded, as in 150.

Fig. 151.—Pistil of Primrose (*Primula*), showing the ovary *o* below the stigma *s* at the top, and the style *st* between them.

Fig. 152.—Pistil of Apricot-tree cut vertically. *vp* outer coat of ovary, *me* middle coat, *end* inner coat, which becomes the stone, *ov* young seed or kernel, *tc* style and its canal, *st* stigma.

pistil of the apricot-tree laid open longitudinally, *st* being the stigma, *tc* the style, with a canal through it, *vp, me,* and *end,* the three coverings of the ovary, and *ov* the young seed.

The carpels or leaves forming the pistil are sometimes separate, as in the common stonecrop (fig. 153), at other times they are united together, as in the primrose (fig. 152), so as to appear as one. The number of carpels forming such a compound pistil can usually be ascertained by cutting across the ovary, as in fig. 154, where it is seen that there are three cavities containing seeds, and consequently three carpels. The ovules or young seeds are generally attached

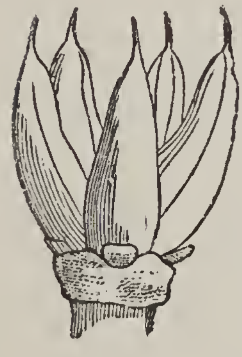


Fig. 153.

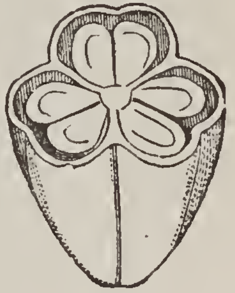


Fig. 154.

Fig. 153.—Pistil (gynœcium) of Stonecrop (*Sedum*). It consists of five carpels, which are separate and distinct. Each carpel has its own ovary, style, and stigma. The pistil is apocarpous or dialycarpous, *i.e.*, is composed of separated carpels. At the base of the carpels are seen scales which are called the nectary. Below the pistil is the part of the receptacle to which the other whorls were attached.

Fig. 154.—Ovary or lower part of the pistil of the Lily (*Lilium*) cut transversely. There are three loculaments, or cavities containing seeds, indicating the union of three carpels, and the ovary is said to be trilocular. The divisions in the ovary, called septa or dissepiments, are formed by the sides of the carpellary leaves. Each septum is double, and the number of septa corresponds with the number of the carpels. The ovules are placed collaterally, in pairs, in each loculament, and are attached to a central point called placenta.

to the edge of the carpels; but sometimes they are united to the axis, as in the primrose, without any apparent attachment to the carpels. In certain cases, as in cycads and conifers, the ovules are not covered by carpels, but are called naked, because the pollen is at once applied to them without the intervention of a stigma. The number of pistils in a flower was used by Linnæus as a mode of distinguishing certain divisions in his system called orders. The Greek numerals were prefixed to the term *gynia*, meaning pistil.

The ovules or young seeds in the pistil are covered by at least two coats, which inclose a central part in which the young plant is formed. At one part of the ovule there is a small opening. In fig. 155 an ovule is represented with its two coverings, within which is the central nucleus *n*, the sac *s* containing a minute cell *c*, in which the embryo *e* is seen near the opening. The nourishing vessels enter the ovule at *ch*. Sometimes the ovule, in place of being straight, is turned

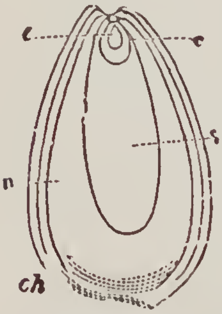


Fig. 155.

Fig. 155.—Orthotropous or straight ovule of Polygonum, showing the coats of the ovule on the outside, the nucleus *n*, the embryo-sac *s*, containing a vesicle *c*, in which the rudimentary embryo *e* is seen close to the foramen or micropyle. The chalaza is marked *ch*.

round, as in fig. 156, where the opening *f* is represented as pointing downwards.

The grains of pollen, when discharged from the anther, are applied to the stigma (fig. 152, *st*), and, after lying on it for a certain length of time, they send out tube-like prolongations, as in fig. 157, where two pollen grains are seen lying on the top of the stigma, which is split open, along with part of the style, to show the pollen tubes. In fig. 158 there is a magnified representation of a pollen grain giving out three tubes, one of which is considerably elongated. These tubes reach the rudiments of the young seed in the ovary (fig. 159), and by this means the embryo plant

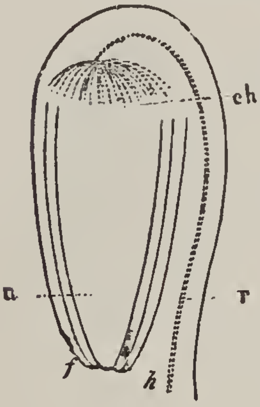


Fig. 156.

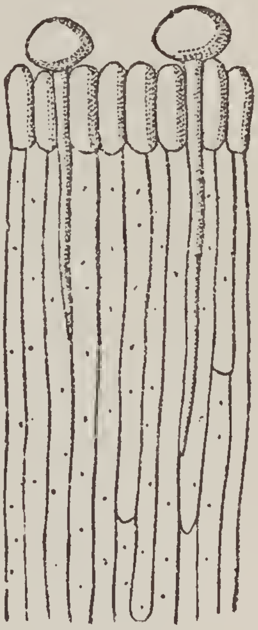


Fig. 157.

Fig. 156.—Anatropous or inverted ovule of Dandelion (*Leontodon Taraxacum*), showing the coats of the ovule surrounding the nucleus *n*, which is inverted, so that its base *ch*, where the chalaza exists, is removed from the base or hilum of the ovule *h*, while the foramen *f* is near the base. The connection between the base of the ovule and the base of the nucleus at *ch* is kept up by means of the raphe or cord *r*.

Fig. 157.—Style and stigma laid open. Two grains of pollen on the top of the stigma protruding tubes, which descend through the stigma and style.

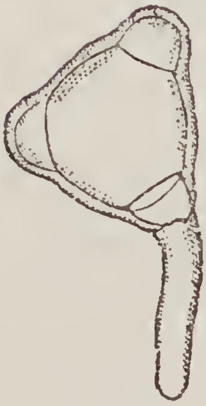


Fig. 158.

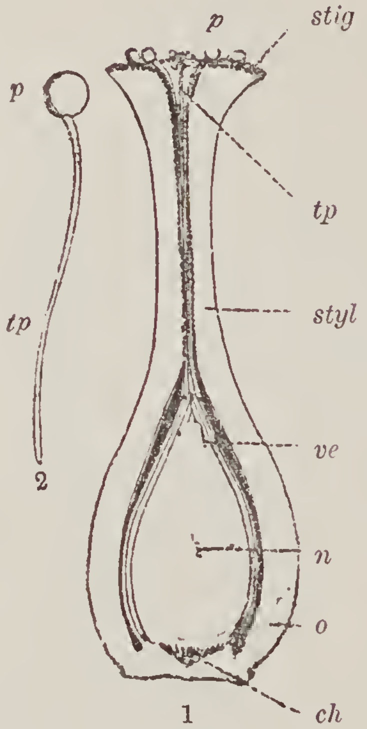


Fig. 159.

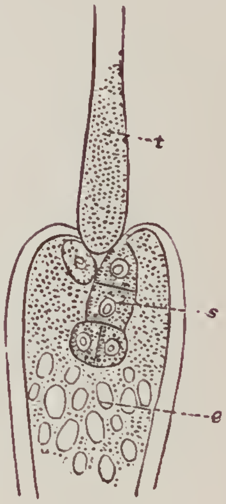


Fig. 160.

is formed (fig. 160). After this process has taken place, the pistil undergoes marked changes, by which it becomes the fruit con-

Fig. 158.—Pollen grain, much magnified, showing three points where tubes come out. One of the tubes is considerably elongated.

Fig. 159.—Pistil and pollen of Polygonum. 1. Stigma *stig*, with pollen grains *p* adherent to it, sending tubes *tp* down the conducting tissue of the style *styl*; the ovary *o*, containing the ovule with its covering and central cellular mass or nucleus *n*, containing a rudimentary embryo-sac *ve*, in which, ultimately, the embryo is developed. The base of the ovule which was attached to the placenta is marked *ch*. 2. Pollen grain *p* separated, tube *tp*.

Fig. 160.—Section of the ovule of Œnothera, showing the pollen tube *t*, with its enlarged extremity applied to the end of the embryo-sac, and introverting it slightly; the germinal vesicle in the sac has been fertilised, and has divided into two parts, the upper part forming a suspensor *s*, and the lower dividing into four parts, which form a globular mass—the rudimentary embryo, surrounded by cells *e*.

taining the seed, in the interior of which is the young germ. It appears that in some instances the embryo plant is produced in the pistil without the application of pollen. This has been noticed in a plant called *Cœlebogyne*, also in hemp, and some other plants.

By taking the pollen of one species of plant and applying it to a different species, seeds are produced which, when they sprout, give origin to what are called hybrids. This effect is probably referred to in Deut. xxii. 9, where it is said, "Thou shalt not sow thy vineyard with divers seeds, lest the fruit of thy seed which thou hast sown, and the fruit of thy vineyard be defiled." Gardeners constantly attempt to produce hybrids, and thus to improve the quality of flowers or fruit, and to get hardy varieties. By inoculating different species of rhododendron, gardeners have secured the fine colour of the Nepal rhododendron with the hardiness of the American species. A vast number of florist's flowers, as varieties of pelargonium, fuchsia, and calceolaria, are hybrids.

IX. ON THE FRUIT AND SEED.

The term fruit, in botanical language, is applied to the mature and perfect pistil, whether dry or succulent. When we examine fruits, however, we shall find them formed in various ways. Some, as the pea, bean, and vetch (fig. 161), consist solely of the pistil, very slightly altered; others, as the grape, peach, and plum, consist of the pistil, changed so as to assume a succulent character, either entirely, as in the grape, or partially, as in stone-fruit; others, as the gooseberry, currant (fig. 162), apple, pear, pomegranate, are formed not only by the pistil, but also by the calyx, a portion of which is seen at the top of these fruits in the form of brownish scales. The hazel-fruit (fig. 163) consists of the pistil developed into the nut, with a covering of

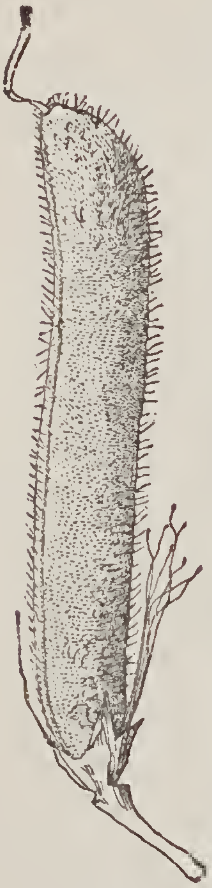


Fig. 161.

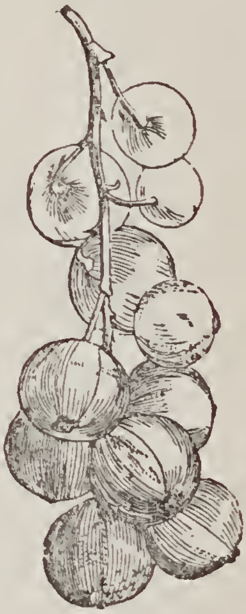


Fig. 162.

Fig. 161.—Pod of Vetch, composed of the pistil, with style and stigma at the summit. The fruit in this case is composed of a single carpel containing numerous seeds.

Fig. 162.—Fruit of Currant, composed partly of the pistil and partly of the calyx; the withered remains of part of the calyx are seen at the summit of each currant.

leaves, called the husk, outside; so also the fruit of the oak, or the acorn, which has a cup-like covering (fig. 164). In the strawberry (fig. 165) the succulent part, which is eaten, consists of the enlarged growing point, bearing on its surface numerous small carpels or fruits, which are often called seeds.* The mulberry (fig. 166), as well as the pine-apple (fig. 167), the bread-fruit, the cone (fig. 168), and the fig (fig. 169), are made up of a congeries of

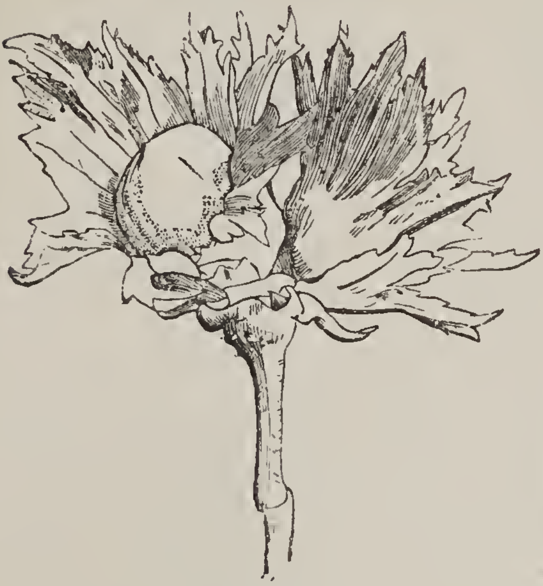


Fig. 163.

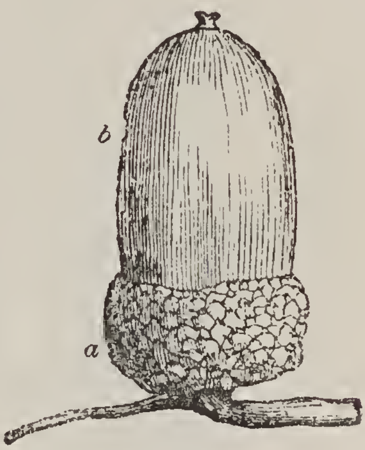


Fig. 164.

Fig. 163.—The fruit of the Hazel, consisting of the nut, with the husk outside. The husk is composed of floral leaves or bracts.

Fig. 164.—Fruit of the Oak or Acorn, with its cup or outer covering of altered leaves or bracts.

* The grain of wheat, and other cereal grains, consist of seeds incorporated with seed-vessels, and are in reality fruits, although they appear like seeds. What, then, is called bare grain in the Bible, is the bare fruit deprived of its husk-like coverings. The Greek word for grain, *Kokkos*, is different from that for seed, *Sperma*.

pistils, formed by separate flowers, and all combined into one mass. In the first four,

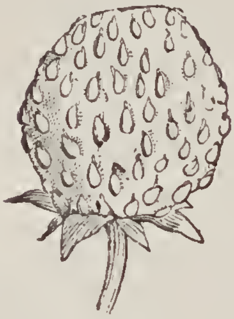
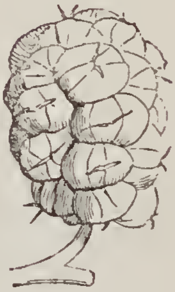


Fig. 165.



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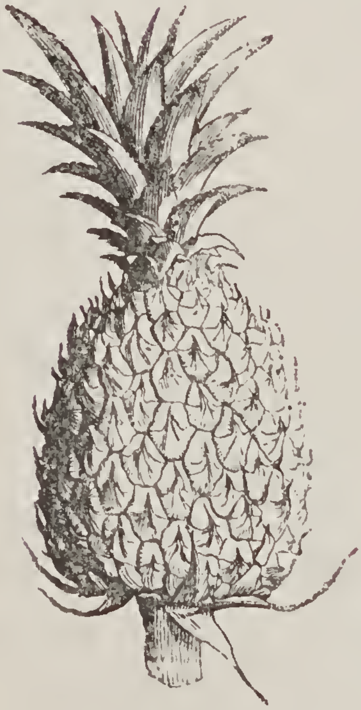

Fig. 167.

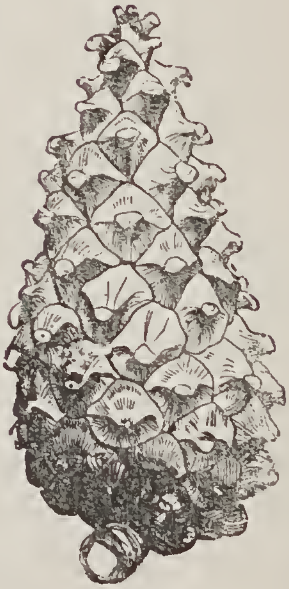

Fig. 168.

Fig. 165.—Strawberry-fruit, consisting of a succulent receptacle, on which are scattered numerous fruits or carpels, resembling seeds.

Fig. 166.—Fruit of Mulberry, composed of the pistils of several flowers united into one mass.

Fig. 167.—Pine-apple, a fruit consisting of several succulent fruits formed by different flowers, and all united into one. The cells outside are modified leaves, while the crown is a series of leaves unaltered.

Fig. 168.—Cone of Fir, a fruit consisting of scales or hardened leaves,

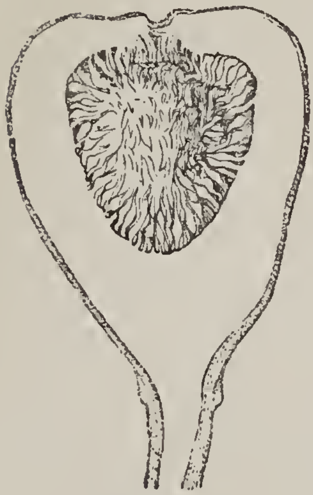

Fig. 169.

the flowers are on the outside of a common receptacle or axis; while in the fig, the succulent receptacle is curved upwards and inwards, so as to be hollow, and thus bears the flowers inside, as seen in fig. 169. In the fig, what are called seeds are in reality fruits, like those on the top of the strawberry, but produced by numerous flowers in place of one.

In the Bible, the term fruit is applied chiefly to edible fruits containing seeds, and growing on trees or shrubs; while grains, which are really fruits, are classed along with seeds. Thus, in Genesis, it is said, "Behold, I have given you every herb bearing seed, which is upon the face of all the earth, and every tree, in which is the fruit of a tree yielding seed" (i. 29). In common language, we apply the name fruit chiefly to that which is succulent and eatable. Various means are adopted by gardeners to

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each representing a separate flower. The fruit is made up of numerous flowers united.

Fig. 169.—Fruit of Fig. This is a succulent stalk, curved so as to form a hollow receptacle, on which numerous flowers are placed, each bearing a single-seeded fruit resembling a seed. The fig-tree has thus no conspicuous blossom; and when it is said in Habakkuk (iii. 17), "although the fig-tree shall not blossom," allusion seems to be made to the green pear-like bud which contains the small flowers.

render edible fruits more fit for the dessert. All the varieties of apple, for instance, are produced from the wild crab by the art of horticulture. The mode in which this has been accomplished is by the process of grafting, or by taking a slip from one tree and making it adhere to the stem of another tree growing in the soil (fig. 170). Grafting is of two kinds. In one case, a slip or graft is taken from a wild tree, bearing comparatively worthless fruit, such as the sour crab-apple, and is attached to a good stock or stem which has been fully matured, and which shows great vigour. Another kind of grafting is accomplished by taking a slip from a tree bearing good fruit, and uniting it with the stock of a wild plant. In both instances good is effected. In the first case, the sap of the excellent stock circulates through the

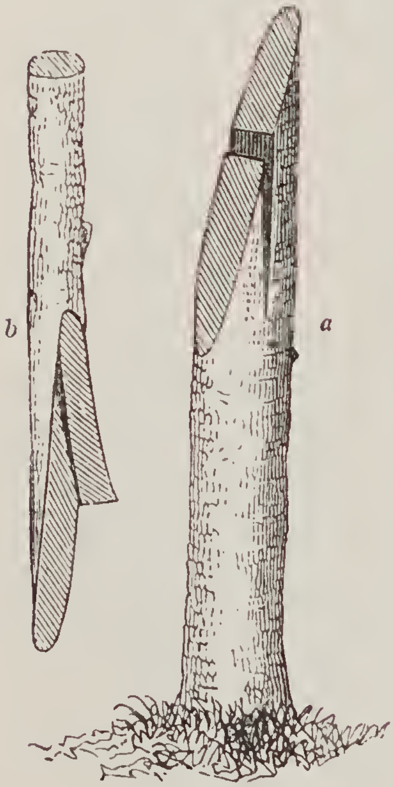

Fig. 170.

Fig. 170.—Whip or tongue-grafting. The stock *a* is cut in such a way as to have a tongue-like process into which the slip or scion *b*, similarly cut, is inserted.

slip or graft, and imparts vigour to it, so as to enable it to produce good fruit. The better the stock on which the graft is placed, and the more nourishing its sap, the more likely is the fruit of the grafted plant to be good. What is called ennobling fruit-trees, is grafting on excellent or well-tried stocks. M. de Jonghe, of Brussels, has shown, by a series of experiments, that the stock has a marked influence on the graft, and that the latter can only produce fruit of an ameliorated character in proportion as it is favourably influenced by the stock. The stock influences the graft as regards the quality and size of the fruit, as well as in regard to the period of ripening. In the second kind of grafting, viz., the insertion of a slip from a good fruit-tree on a crab or wild stock, there is a combination between the two also in such a way as to cause often early flowering and early ripening of the fruit; and thus a useful fruit-bearing tree is produced.

The slip has sometimes a marked influence on the stock. Thus a variegated jessamine, grafted on a non-variegated one, has been known to cause variegation in the leaves produced by the stock. This variegation has also continued even after the slip has been removed. A plan has been recently adopted of grafting flower-buds on the barren spurs of other trees. In this way it is said, excellent pears have been produced.

Grafting is adopted in the case of many fruits, such as apples, pears, grapes, peaches, and plums. By grafting there is for a time an arrestment in the growth of the slip; and it is not until it is fully united to the stock that it grows and produces fruit. If we sow the seed of any apple, however fine, in ordinary soil, and allow it to grow wild, it will revert to the original species, and will produce unpalatable crab-apples. Such is also the case with slips put into the soil. It is only by careful cultivation and grafting that the good varieties are kept up.

The structure of the scion and the stock remains quite distinct, although the sap passes from the one to the other. Thus the scion of a pear engrafted upon a quince stock is still a pear. There is a good reason for this. The pear is developed from the cellular system, and really bears no connection with the quince, except by the sap which flows upward and passes through the cellular system. The cells produced are only pear cells.

Moore performed an experiment of grafting numerous varieties of pear on one stock, and he was thus able to realise, in some measure, the statement in regard to the tree represented as growing in the midst of the street of the New Jerusalem, with the river on either side, and which "bare twelve manner of fruits" (Rev. xxii. 2). It is said, that what are called trifacial oranges, having the character of orange, citron, and lemon, combined in one fruit under a common rind, may be obtained by grafting the embryos of a lemon, a citron, and an orange, in the following manner:—One of the seeds is wholly skinned, so as to lay the embryo quite bare; each of the other two is half skinned; *i.e.*, the skin is taken off one side only. The naked embryo is then placed between the two others, so as to be in contact with their skinned sides, and the whole are bound together with fine grass. They are thus sown; the embryos grow together into one plant, and ultimately the trifacial fruit mentioned is produced.*

The flavour of our table-fruits depends on the presence of certain chemical ingredients. If these are not developed, then the fruit wants some of its characteristics. Even after trees have been grafted, they are apt to run to leaves, in place of flowering and fruiting. In such cases pruning must be adopted, in order to prevent them from becoming rampant. By inflicting an injury on the tree—as cutting a ring out of the bark, or by stopping its roots—gardeners often make barren fruit-trees become productive. The fruit when ripe is usually detached from the tree; but sometimes the fruit of one year remains until that of another is produced. Thus, in the orange-tree, we meet with ripe fruit, green fruit, and flowers, at the same time. At times the fruit appears to be complete, and yet it contains no seeds. Thus seedless grapes and seedless oranges are often met with. In such cases, although the fruit has a fair appearance, it cannot be said to be perfect, for it has not fulfilled the object of its production, namely, the propagation of the plant. High cultivation may have a tendency to induce this state, and it may perhaps depend occasionally on the age of the trees. Bullar states that the thinness of the rind of the St Michael orange, and its freedom from pips, is owing to the latter cause—the trees, when young, producing fruit with thick rinds and plenty of seeds.

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* Lindley's Theory of Horticulture, p. 359.

From all that has been said relative to fruit many important lessons may be drawn. Thus, man in his natural state brings no fruit to perfection (Luke viii. 14); it is, like the crab-apple, unfit for the Master's use. Hosea, in talking of Israel's attempts to exhibit fruit, says, "Israel is an empty vine; he bringeth forth fruit unto himself" (x. 1). It is only when grafted by the great Husbandman into the true Vine (John xv. 1) that man can bring forth good fruit, even unto life eternal (John iv. 36). The Gentiles are spoken of by St Paul as being "cut out of the olive-tree, which is wild by nature, and grafted contrary to nature into the good olive-tree." Here the scion of the wild olive is represented as grafted on the stock of the productive oil-bearing one; and they are called on to remember that they derive their nourishment from the root of the stock, which, being holy, makes the branches holy (Rom. xi. 16, 18). All their sufficiency is thus from Christ alone. Christ has become man; He is perfect man, as well as God; He is the good stock into which the broken-off branches are grafted; He is the bleeding vine, full of sap, by which they are nourished. Thus they are ennobled, made trees of righteousness, which bear fruit abundantly to the praise and glory of their Redeemer. Our blessed Lord says to his disciples, "As the branch cannot bear fruit of itself, except it abide in the vine; no more can ye except ye abide in me. I am the vine, ye are the branches: he that abideth in me, and I in him, the same bringeth forth much fruit; for without me ye can do nothing" (John xv. 4, 5). As the graft is kept in union with the stock by means of the clay which has been applied by the gardener, so is the believer united to Christ by faith, which is the gift of God. The clay-cement keeps the parts together, but has no virtue in itself: so faith is the means of union to Christ—it shows that the Husbandman has been there. The believer has no merit in this; faith cannot save him (James ii. 14), or make him bring forth fruit. It is the union with the Stock which does this. Thus it is that his faith is not dead, being alone (James ii. 17); there is a real, vital engrafting, and faith is seen by the works which are the fruits of it. By the process of spiritual grafting he is, as it were, checked in his own growth, in his self-love and his self-righteousness, and all his sap comes from Christ. He that is joined to the Lord is one spirit (1 Cor. vi. 17). In Him are all his well-springs, and from Him alone he derives all the nourishment and support he needs. Thus it is that he flourishes and brings forth the fruit of the Spirit containing its nine ingredients, "love, joy, peace, long-suffering, gentleness, goodness, faith, meekness, temperance" (Gal. v. 22, 23), every one of which is necessary for the perfect fruit. Some of these ingredients may abound more than others, thus, as it were, imparting a peculiar flavour; but all must be there in greater or less quantity. Love may be looked upon as resembling the substance coming from the stock which unites the graft to it. This love flows from Christ to the grafted believer. "As the Father hath loved me, so have I loved you; continue ye in my love" (John xv. 9). Thus the union is formed, and he becomes identified with the Stock. This love will last through eternity. When the clay is removed in the case of an ordinary tree, the graft is found united to the stock; so when faith is swallowed up in sight, then the perfect union of Christ and His people is seen. Heaven has not to begin, but only to perfect, the living intercourse of believers with Christ and with each other. While on earth they were all grafted into one Stock. They were all one in Christ, who has said, "Neither pray I for these alone, but for them also which shall believe on me through their word; that they all may be one; as thou, Father, art in me, and I in thee, that they also may be one in us: that the world may believe that thou hast sent me" (John xvii. 20, 21). There is another kind of grafting referred to in Scripture similar to the grafting of the good slip on the poor and worthless stalk. This is referred to by James, where he calls upon Christians to "receive with meekness the engrafted word which is able to save their souls" (James i. 21). In this case the word, as a perfect graft, is united to the believer, who is naturally unproductive. This word thus influences his whole character, and enables him to bring forth good fruit,—even an hundred-fold.

Fruit trees are not so much valued for their external appearance, or the symmetry of their forms, as for their fruit. So in the believer, as in his Master, there may be no outward comeliness, nothing to attract the carnal eye, no earthly "beauty that we should desire him" (Isaiah liii. 2), but there is fruit which God's eye can discern, and which is well pleasing in His sight.

"The Saviour comes! no outward pomp
Bespeaks his presence nigh;
No earthly beauty shines in Him
To draw the carnal eye.

"Fair as a beauteous tender flow'r,
Amidst the desert grows,
So slighted by a rebel race
The Heav'nly Saviour rose."

How often do we find those who have nothing to recommend them as regards externals, but who, on the contrary, are despised of men, made the instruments of promoting God's cause on earth, and honoured by Him as His fellow-workers.

We have seen, in the case of fruit-trees, that pruning is often necessary in order to make them bear fruit well; so it is in spiritual fruit-bearing. Too often the believer becomes, as it were, rampant, is elated by worldly fame and reputation, or by the praise of men, and, like the ordinary vine, produces abundance of leaves, but no fruit. He then requires to be pruned, to be put into the furnace of affliction, to have those worldly things or those spiritual acquirements on which he rested lopped off; and thus purged (John xv. 2), he brings forth fruit to the glory of God. The removal of comforts, the humbling of pride and self-complacency, all tend to make the fruit more precious. They constitute the spiritual pruning, the chastening which "yieldeth the peaceable fruits of righteousness" (Heb. xii. 11). When the pruning-knife of affliction has cut off the luxuriant branches of pride and vain-glory, then is the Christian led in deep humility to see that there is no trusting in self. Christ then says to him, " From Me is thy fruit found " (Hos. xiv. 8), even that fruit which shall remain (John xv. 16). As the fruit may have a great show, but contain no seed with the embryo spark of life, and thus fail in fulfilling the object for which it was formed ; so there may be an appearance of spiritual fruit without the vitality of religion. Such fruit, though fair externally, is in reality dead, and fails in the hour of trial. Like seedless fruits, this spiritual state may be produced by human cultivation, by an artificial nourishment, by a fostering of self-righteousness. There has been no true grafting, no implanting of the heavenly life in the soul. While, however, seedless fruits are said to be sometimes naturally produced by old trees, this is not the case with the true Christian ; for he continues to bear true fruit even in old age, being full of sap (Ps. xcii. 14), derived from the one true source of all fruitfulness, in whom it has pleased the Father that all fulness should dwell (Col. i. 19).

The Seed.—This is contained in the seed-vessel, or, in other words, in the fruit (fig. 152, *ov*, p. 218). In order that it may be complete, it must contain the rudiment of the young plant, or what is called the embryo. On removing the skin of the seed, it is sometimes found that this embryo occupies the whole of the interior. This is the case in the bean, pea (fig. 36, p. 48), and lupin, the fleshy cotyledons of which form the great bulk of the seed; so also in the common wall-flower (fig. 171), and other plants of the cruciferous order, such as wall-flower and candytuft. At other times the embryo forms only a part of the seed, as in palms (fig. 172, and fig. 32, p. 42), lychnis (fig. 173), wheat (fig. 41, p. 51), barley and oats (fig. 33, p. 42). In these instances, there is a separate store of nourishing matter, which, after the seed has been sown, is gradually dissolved, so as to be taken up by the plant in the early stages of growth. The former kind of seeds are called exalbuminous, the latter, albuminous.

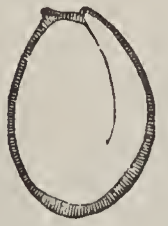
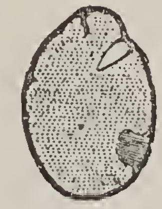


Fig. 171.



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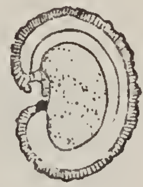


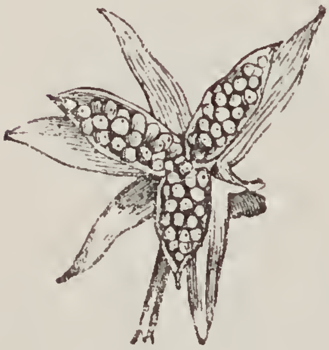
Fig. 173.

Fig. 171.—Seed of common wall-flower, cut open in a vertical manner, showing the embryo plant, of a white colour, occupying the whole of the interior. The coverings of the seed are dark, and a black line indicates the folding of the young root on the cotyledons.

Fig. 172.—Seed of a Palm, cut vertically, showing the minute white embryo occupying only a small part of it. The bulk of this seed is made up by a separate store of nourishing matter, called albumen.

Fig. 173.—Seed of Red Campion (*Lychnis*), cut vertically, showing the embryo curved round the store of nourishment, which is in the centre.

The mode in which seeds are scattered is deserving of notice. In some cases, as in the gooseberry, grape, apple, and coco-nut, the fruit falls without opening, and gradually decays, forming a sort of manure with the soil in which the plant sprouts. In other cases, the seed-vessels open and scatter the seeds. In the pansy, the seed-vessel opens by three valves (fig. 174); in the whitlow-grass by two (fig. 175); in the campion by teeth (fig. 176); in the poppy by pores below the broad stigma



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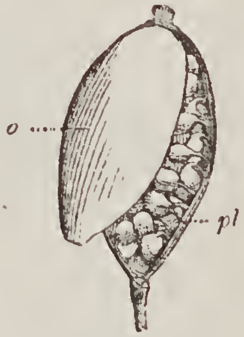

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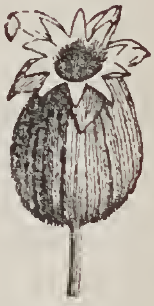


Fig. 176.

Fig. 174.—The capsule of the Pansy (*Viola tricolor*), opening by three valves in a loculicidal manner, *i.e.*, through the back of the carpels. The placentas and seeds are placed on the middle of the valves.

Fig. 175.—Silicula of Whitlow-grass (*Draba*), opening by two flat valves *o*, from below upwards, leaving the parietal placentas *pl*, in the centre, united by a membrane or replum. The seeds are attached to the placentas on either side of the seed-vessel. The partition of the seed-vessel is broad, and hence the name latiseptæ.

Fig. 176.—Seed-vessel or capsule of Campion (*Lychnis*), opening by ten teeth at the apex. The placenta is free central. The calyx is seen surrounding the seed-vessel, but not adherent.

at the top (fig. 177); in the henbane (fig. 178), the pimpernel (fig. 179), and the monkey-pot (fig. 180), by lids. In the common broom the pod when ripe, opens with considerable force

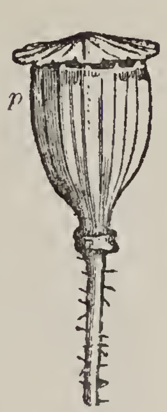
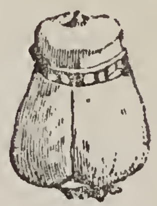


Fig. 177.



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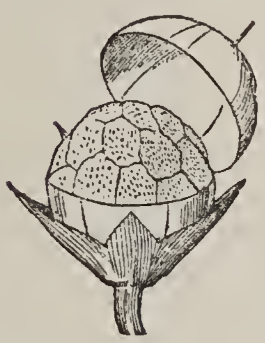


Fig. 179.

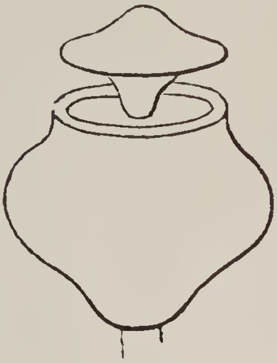


Fig. 180.

Fig. 177.—Capsule of Poppy (*Papaver*), opening by pores *p*, under the broad peltate stigma.

Fig. 178.—Seed-vessel of Henbane (*Hyoscyamus niger*) opening by circumscissile dehiscence. The upper part of the seed-vessel comes off in the form of a lid, and the capsule has been on this account called Pyxis or Pyxidium. The transverse line of dehiscence may be considered as corresponding to the articulations of jointed carpellary leaves like those of the orange,—the lower part representing the united petioles, and the lid the united laminæ.

Fig. 179.—Seed-vessel of the Scarlet Pimpernel (*Anagallis arvensis*), opening by transverse or circumscissile dehiscence. The capsule is called a Pyxis or Pyxidium.

Fig. 180.—Fruit (pyxidium) of the Monkey-pot (*Lecythis ollaria*),

so also the fruit of the sandbox-tree, and the balsam, which is called Touch-me-not, on account of its seed-vessel bursting when touched (figs. 181 and 182). The squirting cucumber, when handled in its ripe state, gives way at the point where the fruit joins the stalk, and the seeds are sent out with amazing force. The common geranium seed-vessels curl up when ripe, as seen in fig. 183, and scatter the

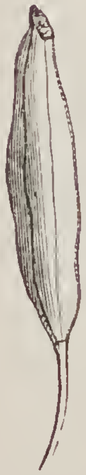
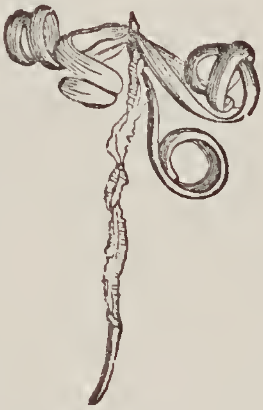


Fig. 181.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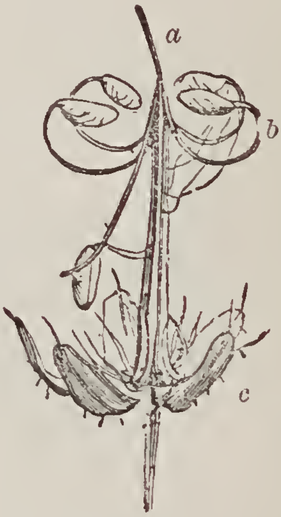

Fig. 183.

opening by a lid. The seeds are the Sapucaya nuts of the shops. They resemble the Brazil nuts, and are relished by monkeys, which are often entrapped when taking the nuts from the interior of the capsule.

Fig. 181.—Ripe fruit of Balsam (*Impatiens noli-me-tangere*), in its unopened condition.

Fig. 182.—Fruit of the same plant opening by five recurved valves. The opening and curvation is traced in part to endosmose taking place in the cells.

Fig. 183.—Fruit of Geranium, showing the different parts of which it is composed curling upwards, so as to scatter the seed.

seeds. In the case of firs (fig. 184), bignonias, and some other plants, the seeds are furnished with winged appendages; while in the cotton-plant and asclepias (fig. 185), they have hairs attached to them, by means of which they are wafted to a distance. The action of moisture in opening seed-vessels is seen (figs. 186 and 187), in the case of a succulent species of fig-marigold from the Cape of Good Hope.

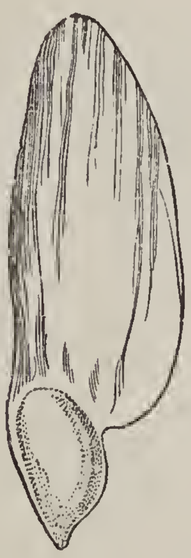

Fig. 184.

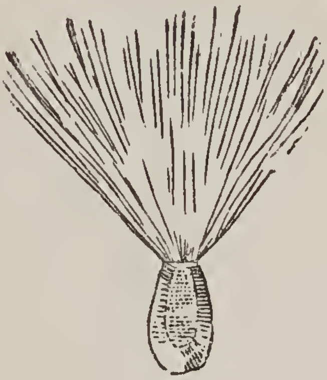

Fig. 185.

In the case of composite plants, such as the dandelion, thistle, and artichoke, what is commonly called the seed is in reality the fruit, with the calyx attached in the form of hairs

Fig. 184.—Winged Seed of Common Fir.

Fig. 185.—Seed of Asclepias, with a cluster of hairs arising from the edges of the micropyle, and by some considered as a hairy aril. These hairs are for the purpose of scattering the seed.

(fig. 132, p. 193). Each fruit contains a single seed, and it is interesting to observe the process by which this single-seeded fruit is deposited in the soil. In these plants there are numerous flowers on a common receptacle, which is at first succulent and nutritive. In the young state this receptacle contains much starch, which is gradually changed into sugar, so as to be easily taken up in solution by the flower. In the artichoke, it is then fit to be used for food. As the flower grows and the fruit is perfected, the receptacle loses its sugary matter and becomes dry. In this state it is unfit for food. Meanwhile the hairy calyx attached to

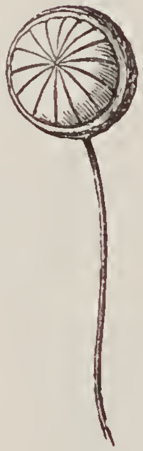

Fig. 186.

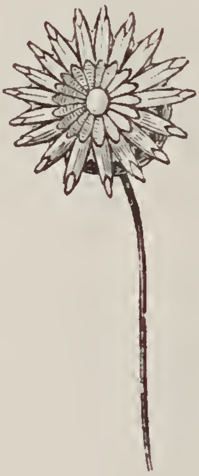

Fig. 187.

Fig. 186.—Seed-vessel of a species of Fig Marigold (*Mesembryanthemum Tripolium*) in a closed state.

Fig. 187.—The same seed-vessel, with its valves expanded, after having been moistened by water. The smelling of the inner cells causes the curvation outwards.

the fruit increases so as to be ready to waft it to a distance. In the dandelion, the leaves which surround the clusters or heads of flowers (fig. 133, p. 193) are turned downwards, the receptacle becomes convex and dry, the hairs spread out so as to form a parachute-like appendage to each fruit, and collectively to present the appearance of a ball, and in this way the fruit is prepared for being dispersed by the winds.

The number of seeds produced by plants is often very great. Thus the Seje palm produces 8000, the common spear-thistle 24,000, the Oriental poppy 32,000, and tobacco 40,000 or more. In the *Gardeners' Chronicle* for November 18, 1854, the following calculations are given :—

	Number of seed-vessels or heads of flowers to each plant.		Number of seeds in each seed-vessel or head of flowers.		Number of seeds in the plant.	When gathered in 1854.
Black Mustard, . . .	800	×	10	=	8,000	Aug. 17
Shepherd's Purse, . .	400	×	10	=	4,000	Sept. 18
Hedge-mustard, . . .	450	×	12	=	5,400	.. 9
Cow-parsnep or Hogweed,	2500	×	2	=	5,000	Aug. 17
Fool's Parsley, . . .	3000	×	2	=	6,000	.. 17
Field Bindweed, . . .	200	×	2	=	400	Sept. 26
Galeopsis Ladanum, .	500	×	4	=	2,000	.. 26
Euphrasia Odontites, .	400	×	12	=	4,800	Oct. 1
Dandelion, ...	12	×	170	=	2,040	.. 1
Black Knapweed, . .	50	×	60	=	3,000	Sept. 10
Common Nipplewort, .	500	×	15	=	7,500	.. 23
Anthemis Cotula, . .	271	×	150	=	40,650	.. 23
Wild Chamomile, . .	150	×	300	=	45,000	Oct. 14
Ox-eye, ...	45	×	300	=	13,500	Sept. 8
Burdock, ...	613	×	40	=	24,520	Oct. 1

	Number of seed-vessels or heads of flowers to each plant.		Number of seeds in each seed-vessel or head of flowers.		Number of seeds in the plant.	When gathered in 1854.
Common Sowthistle,	100	×	250	=	25,000	Sept. 6
Corn Sowthistle,	100	×	190	=	19,000	.. 6
Groundsel,	130	×	50	=	6,500	.. 10
Stemless Thistle,	6	×	100	=	600	.. 8
Nodding Thistle,	25	×	150	=	3,750	Oct. 13
Corn-cockle,	7	×	370	=	2,590	Sept. 8
Red Campion,	25	×	137	=	3,425	Oct. 1
Common Red Poppy,	100	×	500	=	50,000	.. 19
Papaver dubium,	100	×	600	=	60,000	.. 14
Goose-grass,	550	×	2	=	1,100	Sept. 11
Blunt-leaved Dock,	13,000	×	1	=	13,000	.. 15
Euphorbia exigua,	500	×	3	=	1,500	.. 19
.. Peplus,	400	×	3	=	1,200	.. 11
.. Helioscopia,	324	×	3	=	972	Oct. 14

Transported by the agency of man and animals, and carried by means of winds and streams, seeds are deposited in situations fitted for their growth, and under the influence of heat, moisture, and air, the young plant begins to germinate, and goes through the stages of growth which we have already described. In sowing exotic seeds, it is of great importance to determine the temperature of the soil. The seeds of many of our common annuals should not be sown until the ground temperature reaches 46° Fahr. Seeds are often preserved in the soil on account of the temperature of the soil being higher than that of the air. "The winter temperature of the soil," says a writer in the *Gardeners' Chronicle*, "when covered with snow, is in many cases above the freezing point when melting commences, and is considerably augmented before the dormant vitality of the plant is aroused and germination begins. Hooker states, that at Darjeeling, in the Sikkim Himalaya, lat. 27 N. and alt. 7000 feet, the temperature of the earth, at 2 feet 7 inches beneath the surface, was, in December and January, 5° above the monthly mean; in November and February 4 to 5°; in March a few degrees below the mean temperature of the month; and in October above it; April and May, being sunny, it stands above their mean; June and September a little below the mean temperature of each respectively.

"The mean temperature of the soil at 2 to 3 feet is almost, throughout the year in India, above that of the surrounding atmosphere. This is also shown to be the case in England; and Mr Thomson found, at Chiswick, that the temperature of the soil is, on a mean of six years, at the depth of one foot, 1° above that of the air, and at two feet, 1½°. During the winter months, the soil is from 1 to 2° warmer than the air, and during summer, it is a fraction of a degree cooler than the air.

"In India, the mean temperature of the soil in winter may be often 9 to 10° above the air.

The accumulated heat in the upper strata of soil prevents delicate rootlets from becoming frozen, and preserves the vitality in such fleshy roots as rhubarb and orchids. This temperature is also useful to the burrowing rodentia, as hares, marmots, and rats, which abound at 15,000 to 17,000 feet in Tibet. The rapid development of vegetation after the snow is, no doubt, also proximately due to the heat of the soil, quite as much as to the increased strength of the sun's direct rays, on lofty regions."

Seeds often remain dormant in the soil, and only germinate when certain changes take place on the surface. When forests are destroyed, it is frequently observed that a new set of plants make their appearance. Oaks and other plants appear in America after the pine forests have been cleared. Their seeds must have been long in the soil. In Brazil, when a forest has been burned, there succeeds a different kind of vegetation from that previously in the soil. First come up ferns and herbaceous plants, the common sowthistle, some *Solanaceæ*, grasses, *Lobeliaceæ*, and several *Campanulaceæ*. In the second, third, and fourth years this vegetation attains its final growth and dies. Then appear, undershrubs, *Abutilon esculentum*, species of cassia, and other leguminous plants, *Strychnos pseudoquina*, etc. After these, some of which die out in ten years, succeed tall fruit-trees of the genera *Anona*, *Cerasus*, etc.

In order that a plant may be vigorous and healthy, it is of importance that the seed should be good. According to the nature of the seed so is that of the plant produced, and of the fruit which it bears. This is often referred to in Scripture. Thus Eliphaz says, "they that sow wickedness, reap the same" (Job iv. 8); while Solomon states, "to him that soweth righteousness shall be a sure reward" (Prov. xi. 18). "They have sown the wind, and they shall reap the whirlwind" (Hosea viii. 7). "Sow to yourselves in righteousness, reap in mercy" (Hosea x. 12). "The fruit of righteousness is sown in peace of them that make peace" (James iii. 18). The nature of the plant is known by its fruit. "Every good tree bringeth forth good fruit; but a corrupt tree bringeth forth evil fruit" (Matt. vii. 17). This difference in the character of the fruit is illustrated in the parable of the tares and the wheat (Matt. xiii. 24). The object of the husbandman was to get wheat producing grain fit for food, while the enemy endeavoured to thwart his purpose by sowing tares producing no good grain. It is supposed that the tares, or zizania, mentioned in Scripture, were a noxious grass called the Darnel (*Lolium temulentum*), as shown in fig. 188.

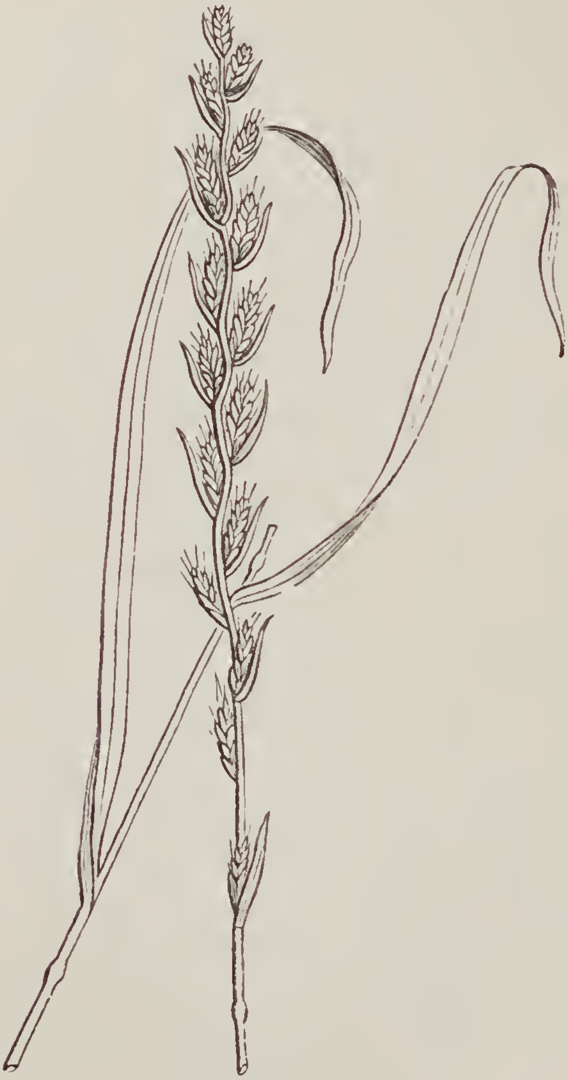

Fig. 188.

Fig. 188.—*Lolium temulentum*, the Darnel-grass, said to be the only poisonous grass; but there are doubts in regard to its narcotic qualities. Some suppose it to be the Zizania or Tares of Scripture (Matt. xiii. 25, etc.), the infelix lolium of Virgil.

In their early stage of growth, these tares, like other grasses or grains, resemble wheat. In this state they can be distinguished by the practised botanist; but if one attempted to separate them, it would be a difficult matter, and there would be great risk of pulling up some young plants of wheat also. When, however, the fruit or grain is produced, that is, at the time of harvest, the characters of the two plants are easily seen, and there is no difficulty in separating the one from the other. Robinson, during his travels in Palestine, saw splendid fields of wheat containing these tares; and it is stated, that wheat, imported from the Continent, is often mixed with darnel. How well, then, do these tares represent those who make a false profession, who appear among God's people, who draw near with their mouth, and honour God with their lips, but their heart is far from Him (Isa. xxix. 13; Matt. xv. 8; Mark vii. 6). Both grow together and may at first seem alike. Man cannot accurately distinguish between the true and the false. But at the great harvest-day the Lord will separate them. He will gather the wheat into His garner, while the tares shall be consumed (Matt. iii. 12; Luke iii. 17).

The soil in which the seed is sown has

a marked effect on its germination and growth. And this furnishes many Bible illustrations. The good seed of the Word does not produce fruit unless it is sown in a soil prepared by the husbandman. There must be a breaking up of the fallow ground (Jer. iv. 3: Hos. x. 12), a preparation of the heart (Prov. xvi. 1), a watering with the dews of the Spirit (Hos. xiv. 5), ere the fruits of the Spirit can be produced. The different kinds of soil into which seed falls is shown in the parable of the sower. Thus we have the hard wayside ground which does not receive the grain, the stony ground with little depth of earth, the soil full of weeds, and the well prepared soil (Matt. xiii., Mark iv., Luke viii).

The duration of the life of plants is a subject of much interest. Flowering and fruiting, in some cases, put an end to the life of the plant; while, in other instances, plants survive this and continue to flower for many years, and even centuries. The annuals of our gardens flower the same year in which their seeds are sown and then die. The henbane produces leaves the year its seeds are sown, flowers the year after, and then dies. The period of flowering in the American aloe is delayed for many years, but when it arrives the life of the plant terminates. The baobab (fig. 189), the dragon tree (fig. 190), the Mammoth pines, yews, and many other trees, flower and fruit in successive seasons through unknown centuries. The age of some of these trees must be very great; but it is not easy to determine it with accuracy. It has been supposed that certain trees now existing on the earth may have been coeval with the creation of man.

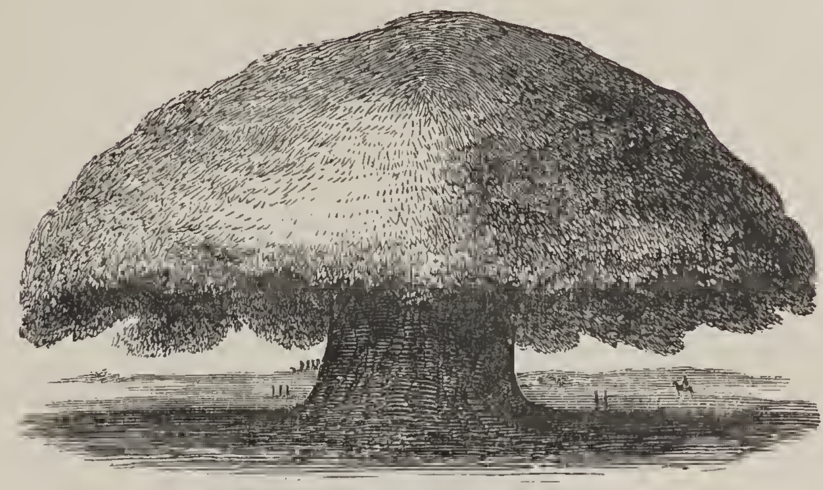

Fig. 189.

A writer in the *Times* gives the following calculation as to the age of the Mammoth pine of California. He says,—" A friend has sent me two specimens of the wood of the *Wellingtonia gigantea.* Of the timber sent there

Fig. 189.—Baobab-tree (*Adansonia digitata*) of Western Africa, having a stem 90 feet in circumference.

are two pieces—one a specimen of the older, or the heart-wood; the other a specimen of the more recent, or the sap-wood. A measured portion of each—an exact inch—has been carefully and repeatedly examined by myself and by half a dozen others, with the naked eye as well as with a magnifying glass; and within that space of one inch we count in the heart-wood more than 45 concentric layers, in the sap-wood more than 21. In fact, 47 and 22½ or 23 respectively, would be within the mark; but let us say, which we were all agreed on, 45 and 21. Now, the tree from which this wood was taken—the Wellingtonia of the Crystal Palace

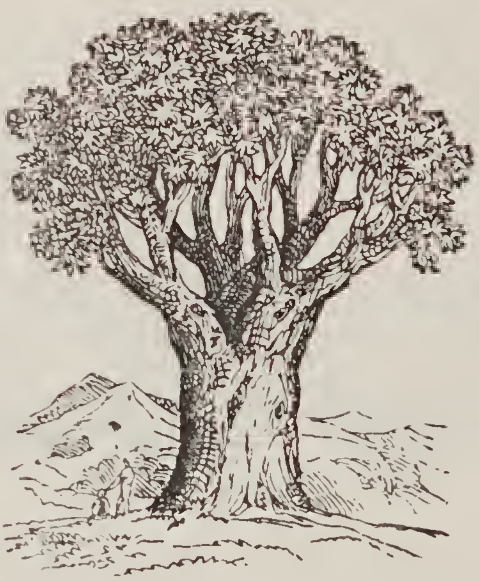
Fig. 190.

Fig. 190.—Dragon-tree (*Dracœna Draco*) of Orotava, having a stem 70 feet in circumference. A more correct representation is given of the Teneriffe tree by Professor Piazzi Smyth.

(now destroyed)—is said to have been 31 feet in diameter at the base. Taking half the diameter (after deducting 18 inches on account of the bark, which was of this thickness), we have 14 feet, or 168 inches, of solid timber, in respect of which we have to compute, as best we may, the number of concentric or annual layers which the tree in question had gathered round it, year by year, from the time it was a sapling until the day it was stripped of its bark and so destroyed. Ascertaining this, we shall be able to form some idea of the age it had attained. It may be assumed that, in such a tree, considerably more than two-thirds of its timber would be heart-wood, and considerably less than one-third sap-wood. Let us suppose, however, that there was 10 feet (or 120 inches) of heart-wood and 4 feet (or 48 inches) of sap-wood. From the foregoing data and assumptions we obtain the following results as to the number of concentric layers, and consequently as to the age of the tree:—

120 inches multiplied by 45 = 5400 layers,
48 ,, ,, 21 = 1008 do.

Making the age of the tree = 6048 years.

If this be considered too high an estimate, on the ground that the piece of heart-wood on which the calculation is based may have been taken from near the centre of the tree, and that, from the compression to which at this depth it had been subjected, it probably contains a larger number of concentric layers within the inch than can be regarded a fair average for the whole of the heart-wood, it will surely be considered a fair average for the whole tree, if we take the mean of the two numbers (45 and 21), or 33 concentric layers to the inch. This would give us (168 × 33) 5544 years as the age of the tree—an age sufficiently venerable.

"It may be excepted to these calculations, that in these trees, speaking generally, the half diameter may not truly represent the actual centre, inasmuch as the trees in question may not grow equally all round; and, if this be so, that in the case of the Crystal Palace tree the pieces of wood examined and measured may both have been taken from the lean or ill-favoured, that is, the exposed side of the tree, on which side the concentric layers, although absolutely as numerous as on the fat or well-favoured side, would be much narrower, and relatively (or within a given space) much more numerous. Yet these trees are, as a whole, remarkably symmetrical. There may, indeed, be some very material error in my calculations; but it does not lie, I am inclined to think, in this direction. The Wellingtonia of the Crystal Palace is described—as it stood in its native grove—as 'having nothing misshapen about it,—as being, on the contrary, a model of symmetry.' The probabilities are that its growth was singularly uniform on every side. Possibly, being evergreens, these Wellingtonias may form more than one layer of wood in the year—three layers in two years, or five in three years. We have no information, so far as known to me, on this point; but, as a source of fallacy may lie here, it is clearly important, before we can absolutely determine as to the age of any one tree of this kind, to ascertain decisively how the case stands in that respect. Meanwhile, I assume, provisionally, that these trees follow, as is probable, the ordinary rule of one layer to the year.

"The concentric layers in the piece of heartwood that belonged to this tree are the most compact that I (who have been a wood-fancier these many years) ever saw; but that they should be as compact as they are will not surprise those conversant with such matters, who reflect on the compressing force to which, year by year, for ages and generations, it must in such a tree have been subjected. And such a force!—acting outwards and stretching, attenuating, and in the end rending the bark, acting inwards and close-packing the timber. Who shall estimate the Bramah-press amount of the power of a layer of living wood 90 feet in girth and 363 in height, confined within a layer of wood and bark, and able to find a space within which to grow and to expand only by using both its elbows in opposite directions? The thickness which, at this stage of the tree's growth, this layer (designated in its embryo state the *cambium* layer) acquires, must be attained by overcoming the enormous *vis inertiæ* of a cone of solid timber within, on the one hand, and of a cone of tough tenacious bark without, on the other, each the accumulated products of many generations. As to the age which these co-Adamite or pre-Adamite trees may yet reach—their expectation of life,—what if, bearing in mind that they grow in a climate particularly favourable to the preservation of the woody matter, and that they are still, old as they are, as fresh and vigorous as in the days of their youth,—what if, unmolested by man, the great destroyer, and the world last as long, they may be alive and flourishing 5000 or 10,000 years hence?" *

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* *Times*, Feb. 18, 1859.

The tree, called *Wellingtonia gigantea* by Lindley, is denominated *Sequoia Wellingtonia* by Seemann, and *Sequoia gigantea* by Endlicher. These mammoth trees were discovered in 1850. The grove is situated near the head waters of the Stanislaus and San Antonio rivers, in the country of Calaveras, lat. 38° N., long. 120° 10′ W., at an elevation of from 4000 to 5000 feet above the level of the sea. Some of the largest trees have been felled. One of them, called the "Father of the Forest," was 112 feet in circumference at the base, and must have been about 350 feet high. Another, the "Mother of the Forest," was felled in 1854, and the bark, to the height of 116 feet, was exhibited in the Crystal Palace. There were ninety-two large specimens growing in the mammoth-tree grove, and most of them had received names. The following list is taken from Dr Seemann's article in the *Annals of Natural History* for March 1859 :—

	Height.	Circumference.	
Hercules,	325 feet	97 feet	
Siamese Twins and their Guardian,	300-325	80	Guardian
Hermit,	320	60	
Mother and Son,	300-320	93	together
Miner's Cabin,	300	80	
Uncle Tom's Cabin,	300	75	
Two Guardsmen,	300	65-70	

	Height.	Circumference.
Beauty of the Forest,	300 feet	65 feet
Old Bachelor, . .	300	60
Addie and Mary, .	300	65
Three Graces, . .	290	92
Pride of the Forest, .	280	60
Old Maid, . .	260	60
Husband and Wife,	250	60
Pioneer's Cabin, .	150	(top broken) 33
Horse-Back Ride, .	150	fallen trunk
Burnt Cave, . .	40 feet 9 inches across at the root,	

besides taller specimens which had been felled. The bark has been measured 18 to 22 inches in thickness.

Many of the trunks are hollowed out into cabins, which can contain a vast number of persons. The bark of the Father of the Forest inclosed a space in which were contained a pianoforte, and seats for forty persons. On one occasion 140 children were in it. The surface of the stump of this tree still remains in the ground. It is smooth, and affords ample space for thirty-two persons to dance—it being 75 feet in circumference. In speaking of this pine, we may use the language of Milton :—

> "To equal which,
> The tallest pine, hewn on Norwegian shores
> To be the mast of some great ammiral,
> Was but a wand."

De Candolle gives the following list of some remarkable trees, the ages of which have been ascertained :—

	Years.
Elm (*Ulmus campestris*), about	335
Cypress (*Cupressus sempervirens*)	350
Cheirostemon platanoides	400
Ivy (*Hedera Helix*)	450
Larch (*Larix europæa*)	576
Chestnut (*Castanea vesea*)	600
Orange (*Citrus Aurantium*)	630
Some Palms (*Ceroxylon* and *Cocos*)	600-700
Olive (*Olea europæa*)	700
Oriental Plane (*Platanus orientalis*)	720
Cedar (*Cedrus Libani*)	800
Lime (*Tilia europæa*)	1076, 1147
Oak (*Quercus Robur*)	810, 1080, 1500
Yew (*Taxus baeeata*)	1214, 1458, 2588, 2880
Taxodium distichum	3000 or 4000
Baobab (*Adansonia digitata*), about	5000

How brief, compared with these periods, is the life of man since the Flood! "Our days are threescore years and ten; and if by reason of strength they be fourscore years, yet is their strength labour and sorrow; for it is soon cut off, and we fly away" (Ps. xc. 10). "Man that is born of a woman is of few days, and full of trouble. He cometh forth like a flower, and is cut down: he fleeth also as a shadow, and continueth not" (Job xiv. 1, 2). The patriarch also contrasts man's life with what takes place in trees, which, although cut down, are capable of living and sending forth shoots: "For there is hope of a tree, if it be cut down, that it will sprout again, and that the tender branch thereof will not cease. Though the root thereof wax old in the earth, and the stock thereof die in the ground; yet through the scent of water it will bud, and bring forth boughs like a plant. But man dieth, and wasteth away: yea, man giveth up the ghost, and where is he?" (Job xiv. 7-10). This description is applicable to many trees, the stems of which, when cut across, are capable of living and sending forth buds. In this way we see what are called pollard trees produced. The description, however, will not apply to such trees as pines and palms.

X. ON THE REPRODUCTIVE ORGANS OF FLOWERLESS PLANTS.

We have traced the various changes which take place in Flowering plants, from the first sprouting of the embryo until the perfect seed is formed and scattered, and we now proceed to give a brief sketch of the same phenomena in Flowerless plants. In them there are no distinct floral organs, such as the calyx, corolla, stamens, and pistil. Certain cellular bodies, however, are found in them, by the union of which it would appear that reproductive germs, equivalent to seeds or to embryo plants, are formed.

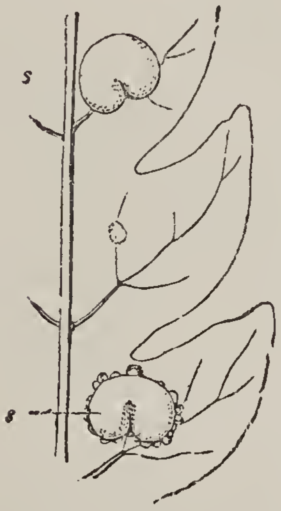

Fig. 191.

In ferns there occur little clusters of minute sacs containing what appears to be brown dust, but which in reality consists of microscopic cellules or germs called spores. These, when scattered in favourable situations, have the power of germinating or sprouting, and thus give rise to new plants. The clusters of sacs or spore-cases are rounded, or linear, or crescent-shaped, and they appear either on the back of the fronds or leaves of ferns, or in the common male Shield-fern (fig. 191), or in the Lady-fern (fig. 24, p. 32), or in spike-like processes, as in the Royal-fern) fig. 192). The little cases or sacs are frequently surrounded by elastic rings (fig. 193), which open them, and thus allow the spores to be scattered. When the spore germinates, it sends out a cellular expansion, as seen in fig. 194 *p*, and from this arises the proper frond. In this frond-like

Fig. 191.—Portion of the frond of the male Shield-fern (*Lastrea Filix-mas*), showing two sori *s s*, or clusters of sporangia or spore-cases covered with a reniform involucre or indusium attached by the sinus.

process *p* are developed certain very minute cellular bodies which are supposed to be equivalent to the stamens and pistils of the flowering plants. In the common Horsetail (*Equisetum*), the little germs or spores are surrounded by two filaments with each of their extremities

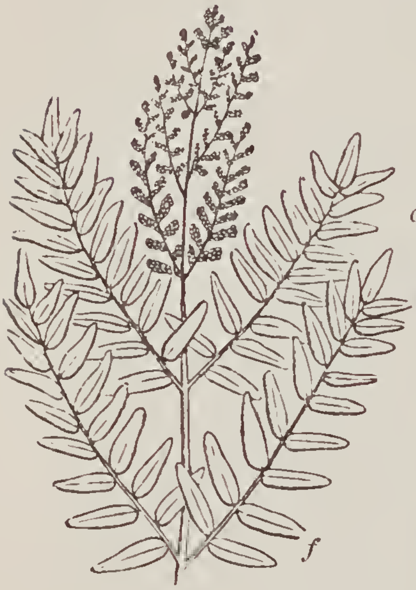

Fig. 192.

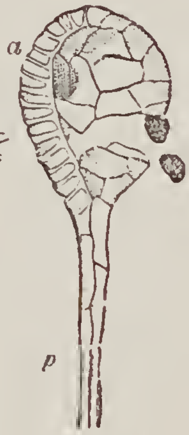

Fig. 193.

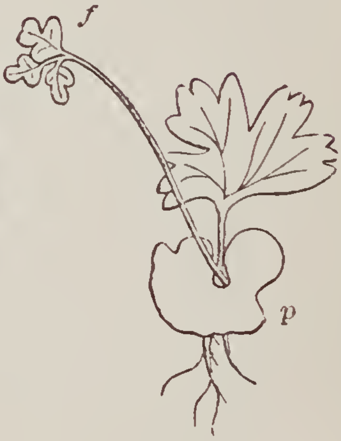

Fig. 194.

Fig 192.—Frond of the Royal-fern (*Osmunda regalis*), bearing divided pinnæ *f*. The frond is bipinnate. At the extremity of the frond the pinnæ are altered so as to bear fructification, consisting of sporangia, arranged in a spike-like manner on a number of short axes. The pinnules, in place of bearing parenchyma, are changed into spore-bearing cells. The morphological changes are often easily traced in specimens in which the pinnæ are partly parenchymatous, and partly sporangiferous.

Fig. 193.—Mature sporangium of the Male-fern (*Lastrea Filix-mas*). It is supported on a stalk *p*, some of the cells of which form an elastic ring or annulus *a* round the spore-case. The spore-case opens at the side to discharge the spores.

Fig. 194.—Young plant of a fern (*Pteris paleacea*), showing the commencement of the sporangiferous frond *f*, arising from the fertilised ovule in the archegonium; the prothallium *p* being still attached.

swollen, as seen in fig. 195. These are remarkably hygrometric, and coil round the spore when moisture is applied, as seen in fig. 196, but spread out when dry, as in fig. 195. They appear to be connected with the deposition of the spore in the soil, and placing it in circumstances fit for its growth. These spores form interesting objects under the microscope. When gently breathed upon, the filaments coil up in a remarkable way, and again expand when dry.

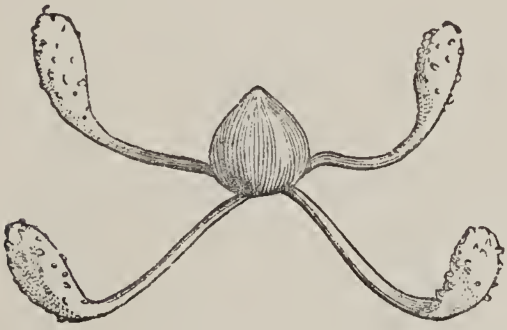
Fig. 195.

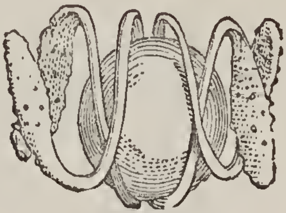
Fig. 196.

In Mosses, the reproductive organs are only seen in the young state of the plant. When the moss is fully developed, the germs or spores are contained in little urn-like cases *u* (figs. 197, 198, and 199), covered by a sort of veil *c*, which falls off and displays a lid *o*. When this lid is

Fig. 195.—Spore of Horsetail (*Equisetum*), surrounded by two filaments with swollen extremities. These filaments are hygrometric.

Fig. 196.—The same spore with the filaments coiled round it.

separated, as seen in fig. 199 *o*, there is displayed a series of processes *p* called teeth, which are very hygrometric, rising up when dry and folding down when moist. These teeth are either four in number or some multiple of four, as 8, 16, 64, 256, etc. They surround the top of the case which contains the spores in its interior.

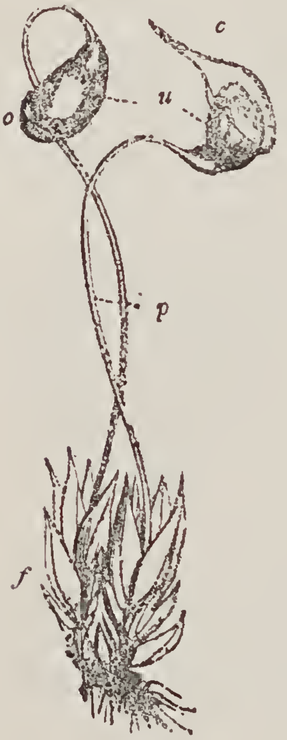

Fig. 197.

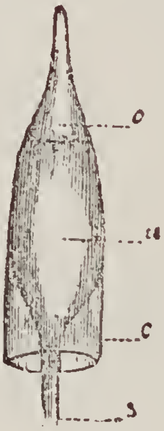

Fig. 198.

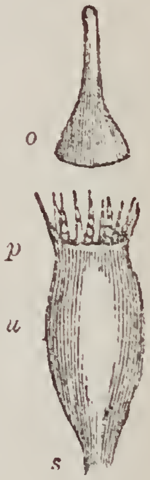

Fig. 199.

Fig. 197.—A Moss (*Funaria hygrometrica*), slightly magnified. Leaves *f* connected with the stalk *p*; *u*, urn-like spore-case, with its veil *c*, and lid *o*.

Fig. 198.—Urn-like case of a Moss (*Encalypta vulgaris*) magnified; *s* stalk, *c* veil, under which, and seen through it, are *u*, the urn-like spore-case, and *o*, the lid.

Fig. 199.—Urn-like case *u* of the same Moss, with the veil removed, and the lid *o* taken off to show the row of teeth *p*; *s*, the stalk bearing the case.

How beautiful is the structure of the smallest moss when fully examined! No wonder that Mungo Park, when seeing the tiny moss called *Fissidens bryoides* expanding its spore-bearing cases in the desert, was led to contemplate with wonder the care which God takes of the minutest parts of creation, and to derive encouragement from this thought in his weary pilgrimage. In the Menziesian Herbarium, at the Botanic Garden, specimens of the moss are preserved as having been received by Menzies from Mungo Park in 1797. The story of Mungo Park is as follows:—

He was robbed by banditti on the 25th of August 1796, when on his road from Kooma to Sebidooloo, and was stripped of everything. "After they were gone," he says, "I sat for some time looking around me with amazement and terror. Whichever way I turned, nothing appeared but danger and difficulty. I saw myself in the midst of a vast wilderness, in the depth of the rainy season, naked and alone; surrounded by savage animals and men still more savage. I was five hundred miles from the nearest European settlement. All these circumstances crowded at once on my recollection, and I confess that my spirits began to fail me. I considered my fate as certain, and that I had no alternative but to lie down and perish. The influence of religion, however, aided and supported me. I reflected that no human prudence or foresight could possibly have averted my present sufferings. I was indeed a stranger in a strange land, yet I was still under the protecting eye of that Providence, who has condescended to call Himself the stranger's Friend. At this moment painful as my recollections were, the extraordinary beauty of a small moss, in fructification, irresistibly caught my eye. I mention this to show from what trifling circumstances the mind will sometimes derive consolation; for, though the whole plant was not larger than the tip of one of my fingers, I could not contemplate the delicate conformation of its roots, leaves, and capsule, without admiration. Can that Being (thought I) who planted, watered, and brought to perfection, in this obscure part of the world, a thing which appears of so small importance, look with unconcern upon the situation and sufferings of creatures formed after his own image? Surely not! Reflections like these would not allow me to despair. I started, and, disregarding both hunger and fatigue, travelled forward, assured that relief was at hand; and I was not disappointed.

In a short time I came to a small village." * A pleasing poetic version of this narrative was given in the *Scottish Christian Herald* many years ago, by the Rev. Robert Murray M'Cheyne.

" The sun had reached his mid-day height,
And poured down floods of burning light
On Afric's barren land:
No cloudy veil obscured the sky,
And the hot breeze that struggled by
Was filled with glowing sand.

. . . . .

" Dauntless and daring was the mind
That left all home-born joys behind,
These deserts to explore,—
To trace the mighty Niger's course,
And find it bubbling from its source,
In wilds untrod before.

" And ah! shall we less daring show,
Who nobler ends and motives know
Than ever heroes dream;
Who seek to lead the savage mind
The precious Fountain-head to find
Whence flows Salvation's stream?

" Sad, faint, and weary on the sand
Our traveller sat him down, his hand
Covered his burning head;
Above, beneath, behind, around,
No resting for the eye he found—
All Nature seemed as dead.

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* "Travels in the Interior Districts of Africa, in 1795, '96, and '97," by Mungo Park, Surgeon, pp. 243, 244. London, 1799. 4to.

"One tiny tuft of moss alone,
Mantling with freshest green a stone,
Fixed his delighted gaze;
Through bursting tears of joy he smiled,
And while he raised the tendril wild,
His lips o'erflowed with praise.

"'Oh, shall not He who keeps thee green,
Here in the waste, unknown, unseen,
Thy fellow-exile save?
He who commands the dew to feed
The gentle flower can surely lead
Me from a scorching grave.'

"The heaven-sent plant new hope inspired,
New courage all his bosom fired,
And bore him safe along,
Till, with the evening's cooling shade,
He slept within the verdant glade,
Lulled by the negro's song.

"Thus, we in this world's wilderness,
Where sin and sorrow, guilt, distress,
Seem undisturbed to reign—
May faint because we feel alone,
With none to strike our favourite tone,
And join our homeward strain.

"Yet often in the bleakest wild
Of this dark world, some heaven-born child,
Expectant of the skies,
Amid the low and vicious crowd,
Or in the dwellings of the proud,
Meets our admiring eyes.

"From gazing on the tender flower,
We lift our eye to Him whose power
Hath all its beauty given;

Who in this atmosphere of death,
Hath given it life, and form, and breath,
And brilliant hues of heaven.

" Our drooping faith, revived by sight,
Anew her pinion plumes for flight,
New hope distends the breast;
With joy we mount on eagle's wing,
With bolder tone our anthem sing,
And seek the pilgrim's rest."

Lichens have been referred to already at pages 7 and 8, and a figure has been given of a common parmelia. These plants form the green and yellow coverings of rocks otherwise bare of vegetation. They occur abundantly in temperate and cold regions. They are found on the inhospitable arctic and antarctic rocks, and are the last traces of vegetable life seen on ascending lofty alpine summits. They consist of a cellular expansion bearing rounded discs (fig. 200), which contain tubes with spores or germs (fig. 201). The latter are very minute, and are easily carried about by the wind. Lichens are the first plants which appear on coral islands, on lava, or on new islands which occasionally appear in the ocean. They have minute cellular organs of reproduction, visible only under the microscope.

Fungi are illustrated by the mushrooms, toadstools, and moulds. They too present little germs attached to various parts of the plants (fig. 202), and sometimes contained in tubes (fig. 203).

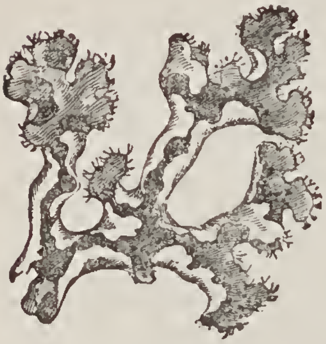

Fig. 200.

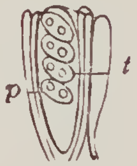

Fig 201.

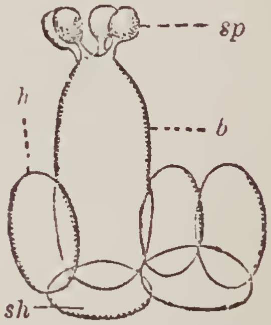

Fig. 202.

In an ordinary mushroom (fig. 204) the following parts are seen; a spawn *my*, consisting of thread-like cells developed underground; from this is produced a stalk *st*, bearing at its summit a cap-like portion *p*, on the under surface of which are seen gills or laminæ *la* and *h*, on which the young germs are placed. From the edge of the cap there extends to the stalk in a young state a thin cellular membrane called a veil, which is finally ruptured, the remains of it forming a ring *an* round the stalk. In the

Fig. 200.—Iceland Moss (*Cetraria islandica*) a species of Lichen, consisting of a foliaceous cellular expansion bearing the fructification.

Fig. 201.—A theca or tube *t*, of a Lichen, containing four nucleated cells. These cells ultimately form the sporidia or sacs containing numerous minute spores. Round the theca are cellular filaments or paraphyses *p*.

Fig. 202.—Part of the fructification of the Mushroom (*Agaricus campestris*). The cellular stratum, bearing the fructification or hymenium is marked *h*, and below it is the sub-hymenial layer *sh*. A basidium or basidial cell *b*, bears at its apex four spores *sp*, which are supported on stalks or sterigmata.

very early state of the plant before it rises upwards, it is enclosed in a wrapper *vol*, which gives way as the mushroom is developed. In moulds (fig. 205), we observe a spawn *m*, which extends itself among the decaying matter, and gives rise to a stalk *f*, which bears the fructification *s*. The minute germs of fungi are dis-

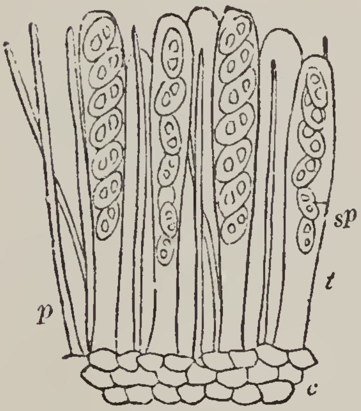

Fig. 203.

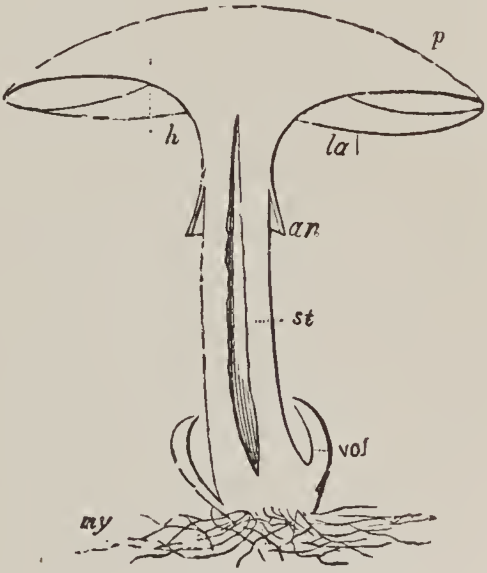

Fig. 204.

Fig. 203.—Vertical section of the fructification of a Fungus (*Peziza*), showing the cellular stratum *c*, bearing clavate spore-cases or thecæ *t*, which contain nucleated cells *sp*. These cells ultimately become sporidia, containing spores. Along with the thecæ are cellular filaments or paraphyses *p*.

Fig. 204.—Vertical section of a mushroom (*Agaricus campestris*); *my*, mycelium or spawn; *vol*, remains of volva or wrapper, which covers the fructification in the young state; *st*, stipe or stalk which is hollow internally; *an*, annulus or ring, being the remains of the velum, veil, or cortina, which extended from the edge of the pileus to the stipe; *la*, lamellæ or gills of the hymenium *h*; *p*, the pileus.

persed everywhere throughout the atmosphere and are ready to light on any substance on which they can find a nidus. Hence, we see mould spring up rapidly wherever there are circumstances to favour its growth. Paste or bread cannot be kept long without becoming mouldy. Fungi grow with astonishing rapidity. Their spawn spreads throughout the soil or decaying matter, and when circumstances are favourable for their growth, the fructifying stalks spring up from various parts of the spawn. Thus crops of mushrooms appear in the course of a single night. One of the puff-balls has grown in a single night, in damp weather, from the size of a mere point to that of an enormous gourd. By a constant division of cells the production of new ones goes on in geometrical progression. Thus, if one cell becomes 2 in the course of 20 minutes, then in 40 minutes 4 will be found, in 1 hour 8, in 2 hours 64, in 3 hours 512, in 6 hours 262,144, and in $11\frac{3}{4}$ hours 47,000 millions. The barrack

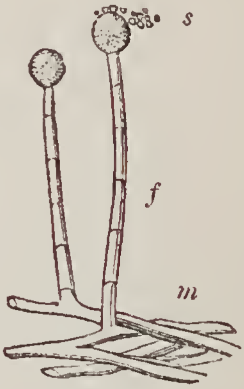

Fig. 205.

Fig. 205.—A species of Mould (*Mucor*), showing the mycelium *m*, bearing a fructiferous stalk *f*, ending in a sac or cystidium *s*, which incloses numerous very minute spores. The spores are discharged by the bursting of the sac.

bread at Paris, a few years since, was perfectly uneatable 24 hours after it had been baked, from the development of a kind of red mould (*Penicillium*) within its substance. Species of coprini or dunghill toadstools occur sometimes on the wood of beds a day or two after they have come from the carpenter's hands. The germs of fungi insinuate themselves into the tissue of animals, and cause their death. Silkworms are liable to a disease called muscardine, which is caused by the attacks of fungi. Wasps in the West Indies suffer in a similar way, so also do caterpillars in Australia.* Even man is liable to be attacked by them, and several diseases of the skin and mucous membrane are said to be caused, or at all events modified, by fungi. Perhaps the leprosy mentioned in the Bible (Leviticus xiii.), and which consisted of a spreading plague deep in the skin, may have been aggravated by the presence of fungi, just as is the case with some skin diseases of the present day. The diseases of grain, such as smut and rust, are due to a similar cause. The entire heads of grain become a powdery mass, so as to illustrate the statement of the prophet, "their blossom shall go up as dust"

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* Specimens of this diseased condition in the West India wasps, and in caterpillars, the latter of which may be seen in the Museum at the Edinburgh Botanic Garden.

(Isa. v. 24). Timber, when not well seasoned, and exposed to the attacks of fungi, without proper ventilation, becomes affected with dry-rot, which is owing to the insidious progress of a fungus, the spores or germs of which insinuate themselves into the wood, begin to form their spawn, and thus speedily cause complete decay. The appearance of such a fungus on the walls of houses may be referred to in Leviticus xiv. 34 to end, where a description is given of what is called the leprosy of the house. This plague extended itself over the wood, the stones, and the mortar of the house, and could only be cured by pulling all down. The spawn of some fungi has been found to attack gutta-percha, and cause great injury to telegraph wires underground. Some telegraph wires passing under oaks have been thus injured.

Algæ or Sea-weeds are plants of a cellular nature, which live either in salt or in fresh water, and which have no floral envelopes, and no stamens nor pistils. Their reproductive germs are either arranged in clusters of four (fig. 206), or are contained in cases or sacs of various kinds (fig. 207). Some sea-weeds are brown-coloured as the common tangle, others are red as the dulse, others as confervæ and lavers are green, while a fourth set are very brittle, on account of having a siliceous or flinty covering.

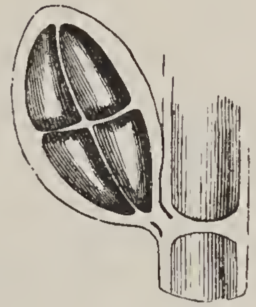

Fig. 206.

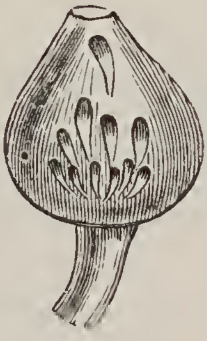

Fig. 207.

In the common sea-weed (*Fucus vesiculosus*), as seen in fig. 208, the frond *f e* displays little bladders of air *v*, which enable it to float, and receptacles of germs *t*, associated with a slimy sort of mucus. Some sea-weeds have stalks several hundred feet long, and their fronds float on the surface of the ocean by means of bladders of air. Some of the fresh-water algæ are composed of simple rows of cells, as seen in fig. 209. These cellular filaments in some instances unite together, as seen in fig. 210, by means of a tube *p*; and in this way the contents of one cell pass into another, so as to

Fig. 206.—Tetraspore of one of the rose-coloured Sea-weeds (*Callithamnion cruciatum*). It is a sac formed by the metamorphosis of the lowermost pinnule of the frond, and contains four germinating spores.

Fig. 207.—Part of the fructification of a rose-coloured Sea-weed (*Bonnemaisonia asparagoides*). It consists of an ovate sac called ceramidium, with a terminal pore, and containing a tuft of pear-shaped germinating cells or spores.

form a germ or spore *gr*. In those plants which are familiar to all as forming the green slime of ponds, there are moving filaments observed, as well as moving spores. The latter, as represented in figs. 211, 212, 213, and 214, are furnished with hair-like processes, which either come off from one point in clusters of two and four (figs. 211 and 212), or more (fig. 213), or they surround the whole spore as with a fringe (fig. 214). These minute hairs exhibit move-

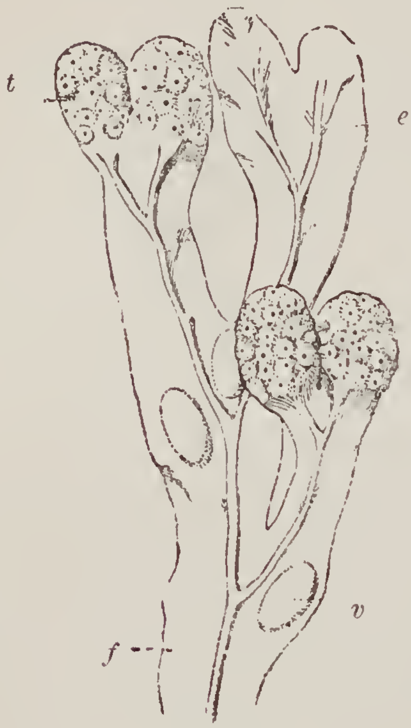

Fig. 208.

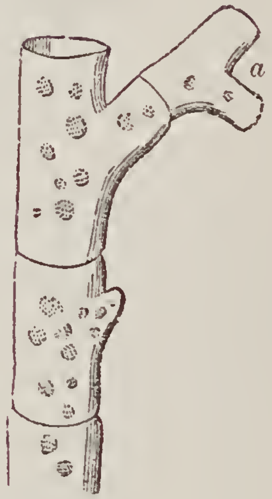

Fig. 209.

Fig. 208.—Frond *f e* of *Fucus vesiculosus* or common Sea-weed; *v*, bladders of air; *t* cases containing spores and mucus.

Fig. 209.—A Conferva or fresh-water Alga, composed of cells with cellular endochrome inside.

ments for a short time after the spores are separated from the plant; their vibration ceasing whenever the spore becomes fixed and begins to sprout. The brittle algæ called diatoms are remarkable for the division of their cells (fig. 215). It has been calculated that, by self-division, one of the diatoms may be propagated at the rate of a thousand millions in a single month. Moreover, by the power of

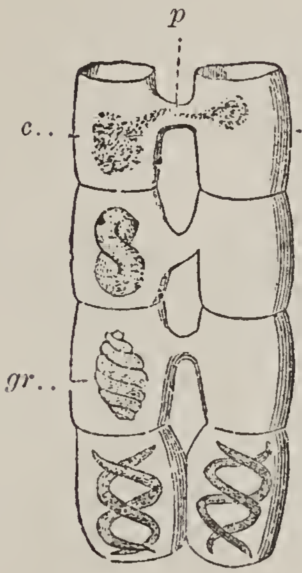

Fig. 210.

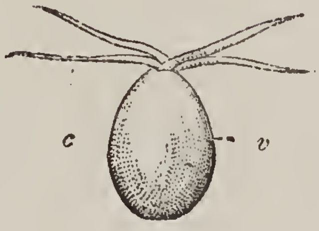

Fig. 211.

Fig. 212.

Fig. 213.

Fig. 214.

Fig. 210.—Two filaments of a fresh-water Alga (*Zygnema*) united by tubes *p*. The contents of one cell *c* pass into another cell *c* on the left, and thus the spore, as seen at *gr*, is produced. In the lowest cells moving thread-like bodies are seen, called phytozoa.

Fig. 211.—Zoospore or sporozoid of one of the Confervæ (*Chætophora*). The spore consists of a vesicle *v*, to which are attached four cilia or vibratile filaments *c*, which move for a certain time after the spore is discharged.

Fig. 212.—Zoospore of Conferva, with two cilia at one end.

Fig. 213.—Zoospore of Conferva, with a tuft of cilia at one end.

Fig. 214.—Zoospore of Vaucheria, surrounded by cilia.

conjugation, cellular bodies, called sporangial frustules, are produced, which are very much larger than the ordinary size of the parent, and which multiply also by self-division. Diatoms occur in all parts of the world, and in some places they form enormous deposits. The city of Richmond, in Virginia, is said to be built on a stratum of diatomaceous remains 18 feet in thickness. The substance called Berg-mehl or Mountain-meal in Sweden is composed of fossil diatoms. The flinty covering prevents them from decaying, and enables them to resist the action of fire and of acids. The markings on many of them are very beautiful, and they constitute excellent test-objects for the microscope.

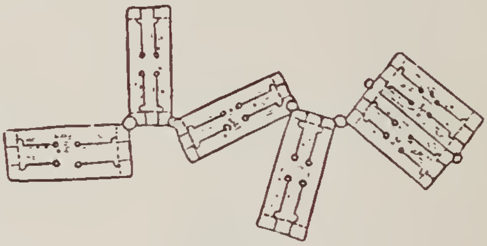

Fig. 215.

In red snow an alga is produced called *Protococcus nivalis*, or the red snow plant. It consists of a minute globular cyst, resembling in appearance a red currant on a very small scale. The plant is met with in the snow of arctic regions. It is not, however, seen in antarctic regions,

Fig. 215.—Frustules of a diatomaceous Alga (*Diatoma marinum*), separating from each other in a merismatic manner. The frustules of the plant vary from nearly square to six times as long as broad, and they present two striæ.

nor did Dr Hooker meet with it on the Himalaya. What is called blood-rain is due to the presence of an alga called *Palmella prodigiosa.* This plant was developed in less than twenty-four hours, under the eye of Dr Montagne, in such quantities as to cover cooked provisions with a dark blood-red slime. The red and green colours seen in the ocean and in lakes are owing to the presence of algæ. Some algæ have a jelly-like appearance, and were formerly supposed to have fallen from the sky, and to be the remains of fallen stars. Hence, species of Nostoc received the names of sky-jelly and star-jelly. In allusion to this, Cowley, in his poem on *Reason* says:—

> "Visions and inspirations some expect
> Their course here to direct:
> Like senseless chemists their own wealth destroy,
> Imaginary gold to enjoy.
> So stars appear to drop to us from sky,
> And gild the passage as they fly;
> But when they fall and meet th' opposing ground,
> What but a sordid slime is found?"

In all the structures to which we have referred, and in the varied changes which the plant undergoes, how beautiful are the adaptations! Everything is guided by unerring wisdom, and contributes to form one harmonious system, in which there is no flaw and no deficiency. All is superintended by an Omniscient Jehovah, whose care extends to the minutest atom. It is an erroneous view to think of God as governing the grand phenomena of nature, and leaving those which are minute to the operation of a set of laws which He does not uphold at every moment in all the fulness of their application. "We cannot," says Chalmers, "disjoin God from one particle of the universe, without desolating the universe of God." We may despise what is small as beneath the notice of our pride, but nothing is too microscopic for Him who, while He measures the waters in the hollow of His hand, and metes out heaven with the span, and comprehends the dust of the earth in a measure, and weighs the mountains in scales, and the hills in a balance (Isa. xl. 12), yet numbers the very hairs of our head, and knows of every sparrow that falls to the ground (Matt. x. 29, 30). The minuteness with which God provides for all wants is well brought out in the 65th Psalm, where David speaks of Him as attending to the very settling of the furrows of the field and the watering of the ridges. "*Thou* makest the outgoings of the morning and evening to rejoice. *Thou* visitest the earth, and waterest it: *Thou* greatly enrichest it with the river of God, which is full of water: *Thou* preparest them corn, when *Thou* hast so provided for it. *Thou* waterest the ridges thereof abundantly: *Thou* settlest the furrows thereof: *Thou* makest it soft with showers: *Thou* blessest the springing thereof. *Thou* crownest the year with Thy goodness; and Thy paths drop fatness." In the minutest events connected with the growth and development of plants, we may apply what David said of the structure of the human frame, "For thou hast possessed my reins: Thou hast covered me in my mother's womb. I will praise Thee; for I am fearfully and wonderfully made: marvellous are Thy works; and that my soul knoweth right well. My substance was not hid from Thee, when I was made in secret, and curiously wrought in the lowest parts of the earth. Thine eyes did see my substance, yet being unperfect; and in Thy book all my members were written, which in continuance were fashioned, when as yet there was none of them" (Ps. cxxxix. 13-16).

CHAPTER III.

ON THE ARRANGEMENT OR CLASSIFICATION OF PLANTS.

When we examine the vegetable kingdom, we find throughout the whole of it a beautiful principle of adaptation, indicating the work and superintendence of a designing mind. This adaptation is seen in the relation which subsists between the plant and the soil and atmosphere with which it is surrounded, as well as in the functions of individual organs, and the mode in which they are made subservient to important ends. We cannot fail, moreover, to observe a wonderful system of order and arrangement both as regards the parts of which plants are composed, and the relations which the members of the vegetable kingdom bear to each other. These two points —*Adaptation* and *Order*—require to be carefully kept in view in explaining the phenomena of vegetation. In many instances, it will be seen that we would fail in presenting a proper view of the vegetable economy, if we merely looked to the physiological use of an organ, *i.e.*, its relation to the parts of the individual plant, and disregarded its bearing in the great order of nature, *i.e.*, its relation to the parts of other plants.

We frequently observe in plants what are called abortive or altered organs, which, as far as regards the usual function of the parts, may be said to be of no use, and would therefore be viewed as imperfections or blots in creation; but when we take into account their connection with the system of arrangement of species, we then are compelled to admit that they are important landmarks in displaying the plan of the Almighty Architect. The teleological reason in such cases (or the end in view) is to be sought not in the individual species taken by itself, but in its relation to other species. The altered organ is not regarded in a functional, but in an ordinal or classificatory sense. Thus, in the non-developed or changed state of organs, we can detect facts which are valuable in the formation of vegetable alliances, and which point out the plan or system of Creation. Such organs also show the symmetrical arrangements which prevail throughout the vegetable kingdom.

By a careful and extended examination, botanists have arrived at certain facts regarding the symmetry of plants. They have found that in the arrangement of the organs or parts of plants, the Creator has adopted marked laws as regards number and position. True, we find that there are many anomalies, and that on the earth, which has been cursed in reference to its produce, there are many causes interfering with complete and full development. Still, amidst this apparent confusion, there are obvious indications of typical forms and arrangement. Just as in regard to man himself, we may not be able to see a perfect human form, but we learn by comprehensive observation what is the type of man, both as regards the framework or osseous portions of his body, and as regards its contour. We can thus detect the plan on which man's bodily frame has been constructed; and the sculptor may to a certain extent embody this in productions of his art. So it is with the plant. Soil, climate, disease, and injuries may interfere, and do interfere, with development, but in spite of all this we can detect the typical idea, as it were, which pervades the whole. Even in the very anomalies there is beauty and harmony; and their existence has been turned to most important uses by man in his attempts to follow the great plan of Creation—the *natural system*, as it is called. Materials have been furnished by these teratological phenomena—these anomalies—for the exercise of man's highest powers of scientific research; and while he thus works out the system of nature, he is led to exalted views of the wisdom of Him who has created all things, and for whose pleasure they are and were created (Rev. iv. 11).

"Ancient philosophers," Agassiz remarks, "studied only morally. Then they took up speculations of physics. Only recently has philosophy turned its attention to the study of plants, of animals, and of the crust of the earth. These studies lead them irresistibly to the conclusion that nature can only be the work of an intellectual Being—of mind—of an individual God. Everywhere there is a diversity among organised beings. Everywhere we find types among them that are identical. The facts, taken together, show that all organised beings have been ordered according to a plan. Thought is visible everywhere; in gealogical distributions, in organic structure and gradation. Everywhere there is an intellectual connection running through the whole. Were we not intellectual beings, allied by the nature of our intellect to the Maker of these, we could not read them. That we can trace the plan, is proof of our mental affinity to the Being that planned it."

We see around us various kinds or sorts of plants which more or less resemble each other, or, in other words, which are more or less related to each other. In systematic botany we endeavour to mark these resemblances, to determine their relation, and to trace out the plan on which they have been arranged by the Great Author of Nature. We must aid the student of botany in his researches, by adopting some classification of the 140,000 known species of plants on the earth. Without this it would be impossible for him to make them available for scientific purposes. In associating plants in certain groups we naturally proceed on the idea of resemblance or likeness. While in ordinary language this idea is often vague and indefinite, in scientific language it must be definite and precise. It is not enough to say that one plant resembles another in its general aspect, we must ascertain the particulars of agreement, and the points in which they differ; we must weigh well the importance of the characters, and compare similar organs; and we must thus be able to give a satisfactory reason for the groups which we form. Many plants which to common observers appear alike, will be found to be very different when the characters are analysed by the man of science.

As they occur in nature, plants are viewed as individuals resembling or differing from each other. Some individuals are so decidedly alike, that we at once give them the same names. Thus a field of wheat is composed of numerous similar individuals which can be separated from each other, but cannot be distinguished by any permanent or marked difference. Although there may be some difference as regards size and other minor points, still we at once say they are stalks of wheat. Every grain of wheat when sown produces a stalk of wheat, and these stalks yield grains which produce individuals like their parents. The shoots or buds given off from the base of wheat by tillering also produce stalks of wheat. From considerations such as these we derive our idea of what is called a *species,* which may be defined as an assemblage of individuals presenting certain characters in common, and derived from one original stock. For each species we believe that there has been a parent stock, which has given origin to a succession of similar individuals. These individuals may differ to a certain extent in size, colour, and other unimportant respects, but they resemble each other more closely than they resemble any other plants, and their seeds continue to produce plants like themselves. The types which constitute the species of living bodies are believed by naturalists to be permanent. There is no evidence of one species being transformed into another. The conversion of oats into rye, and other so-called transmutations of that sort, are mere fictions, which are eagerly adopted by some who desire by means of them to support a false theory of creation, but are rejected by all who wish to ground their statements on the truths of science.

There are no doubt differences in the individuals of a species, depending on soil and on different conditions of heat, light, and moisture. But these differences are not incompatible with the idea of a common origin; and moreover we find, that there is always a tendency to return to the original type. What is called a *variety*, is an individual of a species exhibiting variations which are not in general of a permanent character, and which cannot be kept up in the natural state, or, in ordinary circumstances, by seed. By means of buds or slips such varieties may be continued, but if their seeds are sown in ordinary soil and left to grow wild, the plants tend to return to the specific type. In certain plants, such as cereal crops and culinary vegetables, varieties have been perpetuated from seed by the art of cultivation, and thus races are kept up by artificial means. But when the seeds of such plants are sown in ordinary circumstances and the plants are allowed to grow wild, we then see that there is a return to the parent type. In illustration of this statement we may refer to ordinary vegetables, such as cabbage, cauliflower, brocoli, savoys, and curled greens, which are all derived from one stock or type (*Brassica oleracea*). This plant grows wild on our sea-shores in certain places, and when cultivated it assumes peculiar forms. Thus it forms a heart, as in ordinary cabbage ; its flower-stalks become thickened and shortened, as in cauliflower and brocoli ; or its cellular tissue is largely developed, so as to give rise to the curled appearance of greens. These varieties are continued by cultivation, and after a series of generations, the seeds of the varieties propagate, more or less completely, plants of a similar nature. But if they are allowed to grow wild, then in the progress of time the variations disappear, and the original type of the species is reverted to. The varieties of apples and pears are continued by the art of horticulture and the process of grafting, but the seeds of these plants, when allowed to grow wild, produce the original stock, viz., the crab-apple or crab-pear, whence all the varieties have been produced. All these facts show the permanence of species in nature,and contradict the crude ideas of those so-called naturalists, who state that one species can be transmuted into another in the course of generations.

Having thus determined what species are, we proceed to group them together so as to form a *genus.* This is an assemblage of nearly related species, agreeing with one another in general structure and appearance more closely than they accord with other species. Thus the genus Rosa or Rose includes plants which are obviously allied as regards their general character, their flower, and their fruit. All of them have a well-marked kind of fruit, as seen in the common hep. But under this genus there are numerous species, such as the Scotch Rose, the Dog Rose, the Sweet-briar, and the China Rose, which differ in minor characters, derived from their leaves and other organs. The genus Quercus or Oak includes many species which differ in the form of their leaves and in other respects, but all agree in their catkins, and in the character of their fruit, called an acorn.

Again, in examining genera, it will be seen that some of them, such as Oaks, Hazels, Beeches, and Chestnuts, have a strong resemblance or family-likeness, more especially as bearing catkins, or being what is called Amentiferous, and that they differ remarkably from such genera as Firs and Pines, which bear cones, and from Maples, which bear a winged fruit called a samara. In this way we group genera so as to form what are called *orders* or *families*. While a genus then is a group of allied species, an order is a group of allied genera. Thus Firs, Spruces, Pines, Larches, Cedars, are united together in an order denominated Coniferæ or cone-bearers; while genera having a fruit called a legume are associated under the order Leguminosæ. Sub-orders, or sub-divisions of an order, may be formed also so as to group genera belonging evidently to the same order, but having special points of alliance, and thus facilities may be afforded to the student of botany in his determination of species. Certain orders again are more nearly allied than others, and thus we can group them into larger assemblages called *classes*. Sub-divisions of classes, called sub-classes, are also formed to facilitate reference. The great object is to bring together those plants which are allied to each other in the structure of all their important organs.

We thus arrive at the following divisions:—

- I. Class.
  - Sub-class.
- II. Order or Family.
  - Sub-order.
- III. Genus.
  - Sub-genus.
- IV. Species.
  - Variety.

In giving the name of a plant we express the genus and the species. Thus *Rosa spinosissima* is the Scotch Rose, where *Rosa* is the generic name and *spinosissima* the specific or trivial name; so also *Rosa canina*, the Dog Rose; *Rosa rubiginosa*, the Sweet-briar. In giving the character of classes, orders, genera, and species, we enumerate those marks which are necessary to distinguish them from others in the same category. These are called essential characters, and the shorter they can be made the better. Classes are distinguished by important general points of structure, such as the presence or absence of cotyledons and their number. Orders are distinguished by characters taken from the general structure of the flowers and fruit. In the generic characters we notice the modification of the ordinal characters in a given genus; while in the specific characters are included less important modifications of form, whether in the stem, leaves, or flowers, which serve to distinguish allied species.

The object of this scientific classification is to bring together plants which are allied in all essential points of structure, and thus to follow what may be supposed to be the system of nature or the plan of the Great Creator. To accomplish this requires a full knowledge of the structure of plants all over the world; and hence the systems adopted cannot, in the present state of our knowledge of the flora of the globe, be looked upon as by any means complete. Moreover, we shall find that our divisions will prove, in many cases, more or less temporary or artificial, because in nature there are seldom marked and evident boundaries between groups. One class or order seems to pass into another by insensible gradations. There are no abrupt transitions to suit our precise modes of defining groups. Hence, while we can point out great centres of classification, as it were, round which we can arrange the plants of the globe, we are constrained to admit the incompleteness of all our definitions and lines of demarcation. We meet with aberrant forms which will not suit themselves to our definite groups, and which in fact possess, in a certain degree, characters common to several. Such forms, however, are useful landmarks, and they assist us in seeing the alliances subsisting between different orders. They point out in a very instructive manner the Master Builder's plan; and, although they may puzzle the student who adheres rigidly to definitions given in books, they give to the advanced student of nature enlarged and instructive views of affinities, and lead him to take a comprehensive survey of the plan of creation. On such ideas of affinity and relationship the natural system of botany has been founded by such men as Ray, Jussieu, De Candolle, Brown, Endlicher, Lindley, and Hooker.

Let us endeavour now to give a view of the natural system. In doing this we must take into account the structure and conformation of all parts of plants. Beginning with the elementary tissues, it will be observed that some plants have cellular tissue only in their composition; others have vessels of various kinds. Thus we have two natural divisions

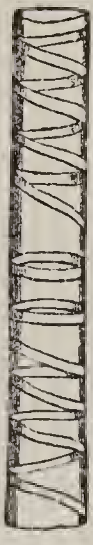

Fig. 216.

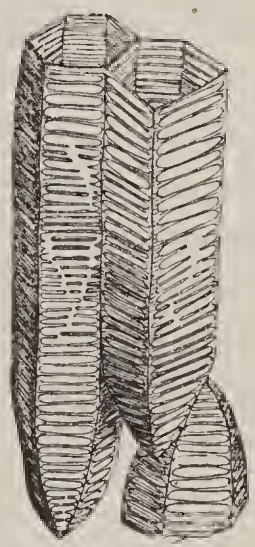

Fig. 217.

of Cellular and Vascular plants. The latter may again be subdivided into those having true unrollable spiral vessels (fig. 216), and those having only modifications of such vessels in the form of scalariform vascular tissue (fig. 217). Cellular plants are represented by sea-weeds, mushrooms, and lichens (fig. 1, p. 8); vascular plants with scalariform vessels by ferns (fig. 24, p. 32); and vascular plants with spiral vessels by ordinary trees, shrubs, and herbs.

If we now take the nutritive organs, we shall arrive also at marked divisions. The embryo plant may be cellular without cotyledons (fig. 39, p. 49), or it may have one or two cotyledons (fig. 34, p. 47, and fig. 37, p. 48). By this means we get the great primary divisions of Acotyledonous plants, such as sea-weeds, ferns, etc.; Monocotyledonous plants, as palms, lilies,

Fig. 216.—Vessel partly spiral and partly annular, taken from the melon plant. In the middle of the vessel a complete fibrous ring is seen, while the fibre at the ends is spiral. The ring is formed by a breaking up of the spiral coil.

Fig. 217.—Scalariform or ladder-like vessels of ferns. The fibre is in the form of bars or lines; and the vessel is prismatic.

and grasses; and Dicotyledonous plants, as peas, beans, and the trees and shrubs of Britain.

Next take stems, and we have plants having Cellular or Thallogenous stems (fig. 1, p. 8), others Acrogenous (fig. 76, p. 99), a third set Endogenous (fig. 67, p. 89), and a fourth Exogenous (fig. 58, p. 76). Leaves furnish the division into plants which are veinless, those having forked veins of the leaf (fig. 230, p. 304), those having parallel venation (figs. 84 and 85, p. 118), and those having reticulated venation (fig. 81, p. 115).

In the next place, consider the organs of reproduction: and here we meet with Flowering plants having proper flowers (fig. 124, p. 180), and Flowerless plants having no such organs (fig. 197, p. 266). In flowering plants the parts of the flower are arranged in threes in one great division (fig. 113, p. 166), and in two, four, and five in another (fig. 112, p. 166). Stamens and pistils, with their seeds, occur in flowering plants (fig. 115, p. 167); cells of a peculiar nature supply the place of these evident organs in flowerless plants (fig. 201, p. 272). On carefully examining these characters we shall find that we can form the following evident divisions, and thus constitute the basis of a natural classification:—

Cellular Plants without Vessels.	Vascular Plants with Scalariform Vessels.	Vascular Plants with Spiral Vessels.	
Acotyledons.	Acotyledons.	Monocotyledons.	Dicotyledons.
Thallogens.	Acrogens.	Endogens.	Exogens.
Veinless.	Forked Veins.	Parallel Veins.	Reticulated Veins.
Flowerless.	Flowerless.	Flowering; flowers with 3-fold Symmetry.	Flowering; flowers with 2-fold or 5-fold Symmetry.
Cellular Organs of Reproduction and Spores.	Cellular Organs of Reproduction and Spores.	Stamens and Pistils, and Seeds.	Stamens and Pistils, and Seeds.

Adopting these general principles of structure and arrangement, and, moreover, taking into account the relative position of different organs—their separation or adhesion—their completeness or incompleteness, we are enabled to construct a plan of classification which has been denominated a natural system. The following are the outlines of this plan :—

A. Phanerogamous or Flowering Plants, with Cotyledons, Stamens and Pistils, and Seeds.

Class I. DICOTYLEDONES or EXOGENÆ, in which spiral vessels are present; the stem is exogenous; venation of leaves reticulated; flowers with binary or quinary symmetry; embryo dicotyledonous.

Sub-class I. Thalamifloræ.—Flowers usually with calyx and corolla, petals separate, inserted on the thalamus, and stamens hypogynous (figs. 218 and 219).

Sub-class II. Calycifloræ.—Flowers usually with calyx and corolla, petals either separate or united, stamens either perigynous (fig. 220) or epigynous (fig. 221).

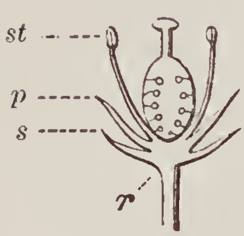

Fig. 218.

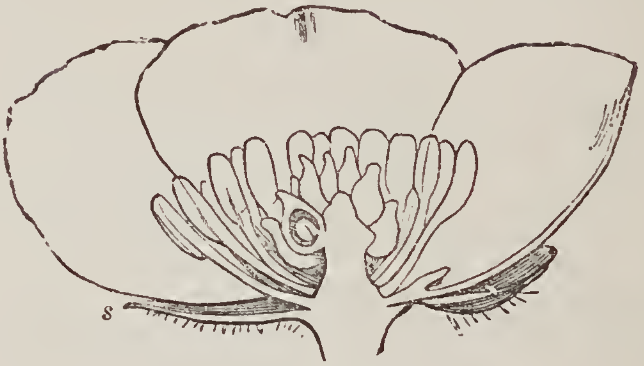

Fig. 219.

Section 1. *Polypetalæ.*—Petals separate (fig. 222).

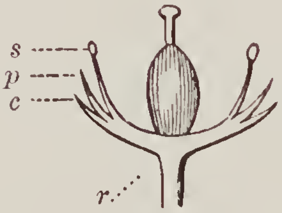

Fig. 220.

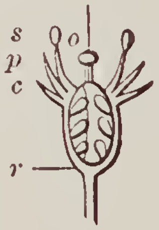

Fig. 221.

Section 2. *Monopetalæ or Gamopetalæ.*—Petals united (fig. 223).

Sub-class III. Corollifloræ.—Flowers usually having calyx and corolla, petals united, corolla hypogynous (fig. 224).

Fig. 218.—Diagram to illustrate Thalamifloral Dicotyledons. Sepals *s*, petals *p*, and stamens *st*, all free, and inserted into the receptacle *r*, below the ovary.

Fig. 219.—Flower of a Ranunculus, illustrating Thalamifloral Exogens. The petals are separately inserted on the thalamus, and the stamens are hypogynous.

Fig. 220.—Diagram to illustrate Calycifloral Dicotyledons with perigynous stamens. Petals *p*, and stamens *s*, inserted on the calyx *c*, surrounding the ovary.

Fig. 221.—Diagram to illustrate Calycifloral Dicotyledons with epigynous stamens. Petals *p*, and stamens *s*, united to the calyx *c*, and all adherent to the ovary *o*, so as to be above it; *r* receptacle.

Sub-class IV. MONOCHLAMYDEÆ or APETALÆ.—Flowers either with calyx only (fig. 225), or without any envelope (fig. 226).

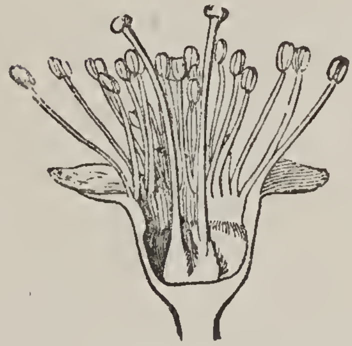

Fig. 222.

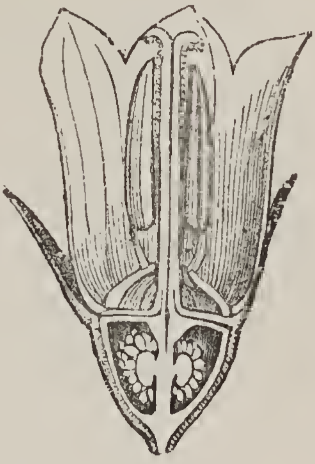

Fig. 223.

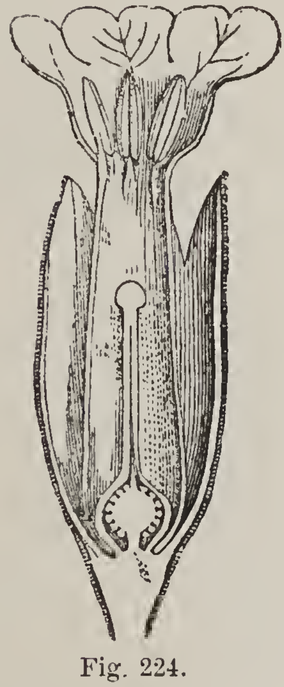

Fig. 224.

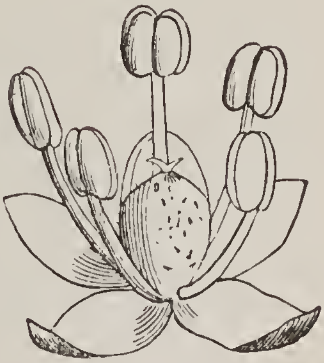

Fig. 225.

Fig. 222.—Flower of Cherry, one of the Rosaceæ, showing a Calycifloral Exogen, with a polypetalous corolla.

Fig. 223.—Flower of Campanula, showing a Calycifloral Exogen, with a gamopetalous corolla.

Fig. 224.—Flower of Primula, showing a Corollifloral Exogen, with the stamens united to the corolla, which is hypogynous.

Fig. 225.—Flower of Chenopodium, showing a Monochlamydeous or Apetalous Exogen.

Section 1. *Angiospermæ.*—Seeds contained in a seed-vessel, and ovules fertilised by the action of the pollen on the stigma.

Section 2. *Gymnospermæ.*—Seeds naked, and ovules fertilised by direct action of the pollen upon them, without the intervention of a stigma (fig. 227).

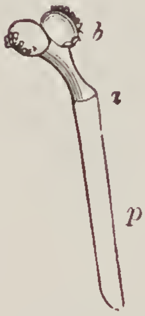

Fig. 226.

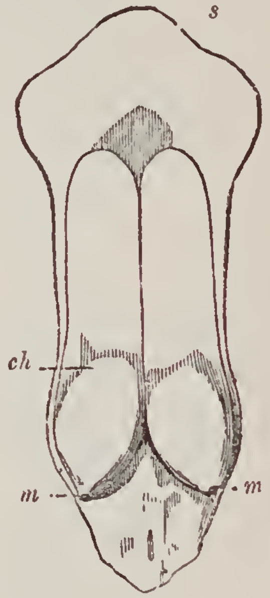

Fig. 227.

Class II. MONOCOTYLEDONES or ENDOGENÆ, in which spiral vessels are present ; the stem is endogenous ; venation of leaves parallel ; flowers with ternary symmetry ; embryo monocotyledonous.

Sub-class I. Petaloideæ.—Flowers consisting of a coloured perianth (fig. 228), or of whorled scales.

Section 1. *Epigynæ.*—Perianth adherent, and ovary inferior (fig. 113, p. 166).

Section 2. *Hypogynæ.*—Perianth free, and ovary superior (fig. 228).

Fig. 226.—Achlamydeous staminiferous flower of Euphorbia, one of the Dicotyledons. Peduncle *p* ; *b* the solitary stamen or staminiferous flower attached to the peduncle by a joint *a*.

Fig. 227.—Scale of a mature cone, with two winged seeds at the base, the micropyle or opening in the seeds *m m*, and the chalaza or base of nucleus *ch*.

Sub-class II. GLUMIFERÆ.—Flowers consisting of imbricated glumes or bracts (fig. 229).

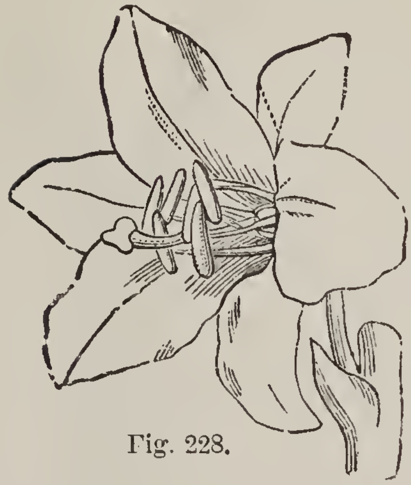

Fig. 228.

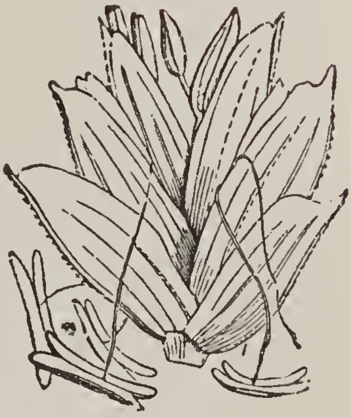

Fig. 229.

B. CRYPTOGAMOUS OR FLOWERLESS PLANTS, WITHOUT COTYLEDONS, AND WITH NO TRUE STAMENS NOR PISTILS.

CLASS III. ACOTYLEDONES, plants either cellular or having scalariform vessels; stem when woody is acrogenous; leaves veinless or with forked venation (fig. 230); reproductive organs peculiar cellular bodies and spores; no cotyledons.

Sub-class I. ACROGENÆ.—Having a distinct leafy stem (fig. 231), with scalariform vessels (fig. 217, p. 297).

Sub-class II. THALLOGENÆ.—Having no distinct stem nor leaves, but forming a cellular expansion or thallus without vessels (fig. 200, p. 272).

Under these classes and sub-classes are included numerous orders, the names of which

Fig. 228.—Ternary symmetry in a perfect flower of a Monocotyledon (*Lilium album*).

Fig. 229.—Glumiferous Monocotyledon (*Triticum*), consisting of numerous flowers formed by imbricated bracts.

are usually derived from some typical genus. In the following tables a short analysis is given of some of the orders, with their general properties:—

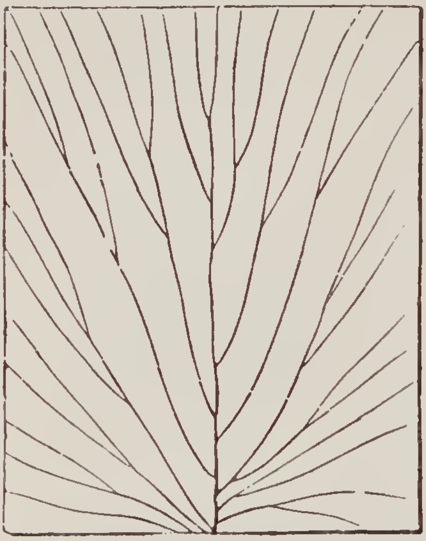

Fig. 230.

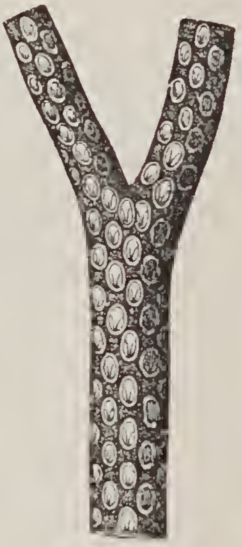

Fig. 231.

ANALYSIS OF SOME OF THE ORDERS IN THE CLASS DICOTYLEDONES.

Sub-class—THALAMIFLORÆ.

I. Stamens indefinite (more than twenty).
  1. Leaves exstipulate (without stipules).
    Leaves forming pitchers, stigma umbrella-like.—*Sarraceniaceæ.*
    Leaves not forming pitchers.
      a. Stamens distinct (free or not united).
        Sepals and petals definite.
          Albumen absent.
            Anthers adnate, stigmas sessile.—*Guttiferæ* or *Clusiaceæ,* fruit sometimes eatable (Mangosteen), purgative acrid juice (Gamboge).

Fig. 230.—Forked venation of the frond of a Fern.
Fig. 231.—Acrogenous woody stem of a Fern.

Anthers versatile, stigmas on a long style.—*Ternströmiaceæ*, stimulating (Tea).

Albumen ruminate.—*Anonaceæ*, aromatic, fruit edible (Custard Apple).

Albumen uniform.

Carpels distinct, sap transparent.—*Ranunculaceæ*, acrid, narcotic, poisonous (Black Hellebore and Aconite).

Carpels united, sap milky.—*Papaveraceæ*, narcotic (Poppy, Opium).

Sepals and petals numerous, passing into each other.—*Nymphæaceæ*, slightly astringent (Water-lily).

b. Stamens polyadelphous.—*Hypericaceæ*, resinous, purgative (St John's Wort).

2. Leaves stipulate (with stipules).

a. Calyx persistent.

Sepals imbricate.

Anthers two-celled.

Sepals irregular.—*Cistaceæ*, balsamic (Labdanum).

Sepals equal.—*Flacourtiaceæ* or *Bixaceæ*, purgative and stomachic (Arnotto).

Sepals valvate.

Stamens monadelphous.

Anthers one-celled.—*Malvaceæ*, mucilaginous (Marsh Mallow Cotton).

Anthers two-celled.

Stamens columnar, extrorse.—*Sterculiaceæ*, mucilaginous (Silk Cotton).

Stamens not columnar, introrse.—*Byttneriaceæ*, mucilaginous and stimulant (Chocolate).

Anthers free.—*Tiliaceæ*, demulcent (Lime-tree).

b. Calyx deciduous.—*Magnoliaceæ*, bitter, tonic, aromatic (Magnolia and Winter's Bark).

II. Stamens definite (less than twenty).

1. Leaves stipulate, carpels consolidated.

a. Placentas parietal.

Petals five.

Leaves with circinate vernation, stipules fringed. —*Droseraceæ*, acrid (Sun-dew).

Leaves with involute vernation, stipules not fringed.—*Violaceæ*, emetic (Violet).

Petals more than five, lacerated.—*Resedaceæ*, fragrant (Mignonette).

b. Placentas central.

Fruit beaked, gynobasic, separating into five cacoons.—*Geraniaceæ*, astringent.

Fruit without a beak.

Albumen absent.—*Sapindaceæ*, leaves poisonous (Buck-Eye), fruit edible (Litchi, Longan, Guarana).

Albumen present.

Stamens more or less united, and alternate with petals.—*Oxalidaceæ*, acid (Wood-sorrel).

Stamens not united, opposite the petals.—*Vitaceæ* or *Ampelideæ*, fruit eatable (Vine).

2. Leaves exstipulate.

Carpels distinct.

Anthers opening by recurved valves, fruit a berry or capsule.—*Berberidaceæ*, acid (Barberry).

Opening of anthers not valvular, fruit a samara. —*Aceraceæ*, saccharine (Sugar-maple).

Carpels united into one.

Stamens tetradynamous.—*Cruciferæ*, pungent, stimulant (Mustard).

Stamens mon- or di- adelphous.

Sepals five, two larger, coloured.—*Polygalaceæ*, stimulant, astringent (Senega).

Sepals two, deciduous.—*Fumariaceæ*, diaphoretic, aperient (Fumitory).

Stamens neither tetradynamous nor united.

Seeds exalbuminous.

Leaves dotted.—*Aurantiaceæ*, pulp of fruit more or less acid, plants yield oil (Lemon, Orange Citron).

Leaves not dotted.—*Capparidaceæ*, stimulant (Capers).

Seeds albuminous.

Styles distinct, leaves not dotted.—*Caryophyllaceæ*, inert.

Styles united, leaves dotted.—*Rutaceæ*, bitter, anthelmintic (Rue), antispasmodic (Bucku), febrifuge (Augostura).

Sub-class—CALYCIFLORÆ. *Section*—POLYPETALÆ.

I. Carpels distinct or but slightly adherent, each having a style and stigma.

1. Leaves stipulate.

a. Leaves without dots.

Carpels numerous, distinct (if solitary not a legume), calyx with odd lobe superior.—*Rosaceæ*, astringent (Rose).

Suborder: *Pomeæ*, fruit eatable (Apple, Pear).

——— *Amygdaleæ*, fruit eatable (a drupe), bark tonic; prussic acid (Peach, Cherry-laurel).

——— *Potentillidæ*, fruit achenes or collective drupes, eatable (Strawberry and Raspberry).

——— *Sanguisorbeæ*, astringent (Burnet).

Carpel solitary, a legume, calyx with odd lobe inferior.—*Leguminosæ*, leaves and fruit eatable (Pulse).

Suborder: *Papilionaceæ*, nutritive (Beans and Peas), poisonous (Scarlet-runner and Laburnum).

——— *Cæsalpinieæ*, purgative (Senna).

——— *Mimoseæ*, astringent, mucilaginous (Catechu, Gum).

b. Leaves with dots.

Plants abounding in balsamic juice.—*Anacardiaceæ* or *Terebinthaceæ*, resinous, acrid, and astringent, fruit sometimes eatable (Cashew, Sumach, Mango).

2. Leaves exstipulate.
    - Styles two.—*Saxifragaceæ*, astringent (Saxifrage).
    - Styles more than two.—*Crassulaceæ*, acrid (Stone-crop).

II. Carpels united, forming an inferior ovary.

1. Flowers with a coronet or ring with abortive stamens.
    - Plants with stinging hairs, leaves exstipulate.—*Loasaceæ*, irritant (Chili-nettle).
    - Plants without stinging hairs, leaves stipulate.—*Passifloraceæ*, subacid (Granadilla).
2. Flowers without a coronet or ring of abortive stamens.
    - *a.* Placentas central.
        - Leaves with pellucid dots and intramarginal veins.—*Myrtaceæ*, aromatic, stimulant, bark astringent (Cajeput, Cloves).
        - Leaves without pellucid dots.
            - Stamens indefinite.—*Lecythidaceæ*, seeds eatable (Brazil-nuts, Sapucaya-nuts).
            - Stamens definite.—*Onagraceæ*, mucilaginous (Willow-herb).
    - *b.* Placentas parietal.
        - Flowers monœcious or diœcious.
            - Stem climbing by tendrils, herbs.—*Cucurbitaceæ*, purgative (Colocynth and Elaterium), eatable (Melon and Gourd).
            - Stem not climbing by tendrils, trees.—*Papayaceæ*, fruit eatable (Papaw).
        - Flowers perfect (all having stamens and pistils).
            - Petals indefinite.—*Cactaceæ*, subacid (Indian Fig).
            - Petals definite.
                - Ovary one-celled.—*Grossulariaceæ*, fruit eatable (Gooseberry and Currant).

Ovary two-celled, stem hollow, flowers in umbels.—*Umbelliferæ*, poisonous (Hemlock), Stimulant and eatable (Parsley, Parsnep), fruit aromatic (Caraway).

Sub-class—CALYCIFLORÆ. *Section*—MONOPETALÆ OR GAMOPETALÆ.

Anthers dehiscing by pores.—*Vacciniaceæ*, acid (Cranberry).
Anthers not dehiscing by pores.
  Ovary one-celled.
    Anthers united.—*Compositæ*, bitter (Chamomile, Thistle), narcotic (Lettuce).
      Suborder: *Cynarocephalæ*, receptacle eatable (Artichoke).
      ——— *Cichoraceæ*, milky, diuretic, and narcotic (Dandelion, Lactucarium).
      ——— *Corymbiferæ*, bitter (Chamomile).
      ——— *Labiatifloræ*, bitter (Mutisia).
    Anthers free.
      Fruit, a single achene without any rudimentary ones.—*Dipsacaceæ*, used in cloth dressing (Teazel).
      Fruit, an achene with the rudiments of two others. — *Valerianaceæ*, antispasmodic (Valerian).
  Ovary two or more celled.
    Leaves opposite.
      Interpetiolary stipules.—*Cinchonaceæ*, febrifuge (Jesuit's Bark), emetic (Ipecacuan), stimulant (Coffee).
      Without stipules.—*Caprifoliaceæ*, emetic, purgative (Honeysuckle, Snowberry).
    Leaves whorled.—*Galiaceæ* or *Stellatæ*, dye (Madder).
    Leaves alternate.
      Anthers free.—*Campanulaceæ*, slightly acid (Hare-bell).

Anthers united—*Lobeliaceæ*, acro-narcotic (Indian Tobacco).

Sub-class.—COROLLIFLORÆ.

I. Flowers regular, stamens equal in length, or at least not didynamous.

Ovary four-lobed externally, fruit four achenes.—*Boraginaceæ*, mucilaginous (Borage), dye (Alkanet).

Ovary undivided.

Carpels four, five, or more.

Stamens opposite the petals.—*Primulaceæ*, acrid and sedative (Primrose and Cowslip).

Stamens alternate with the petals.

Anthers opening by pores.

Two-celled and with appendages.—*Ericaceæ*, astringent (Erica), narcotic (Rhododendron).

One-celled, no appendage.—*Epacridaceæ*, fruit of some eatable (Lissanthe).

Anthers not opening by pores.

Twining plants, corolla plaited, embryo curved.—*Convolvulaceæ*, purgative (Jalap, Scammony).

Leafless plants, corolla not plaited, embryo spiral.—*Cuscutaceæ*, acrid (Dodder).

Carpels only two.

Stamens two.—*Oleaceæ*, laxative (Olive).

Stamens four or five.

Leaves opposite.

Single one-celled ovary.—*Gentianaceæ*, bitter tonic (Gentian).

Two-celled ovary, or two ovaries or follicles.

Filaments distinct, pollen granular, seeds not hairy.—*Apocynaceæ*, milk and fruit poisonous (Nux Vomica), bark sometimes febrifuge.

Filaments united to style, pollen in

masses, seeds hairy.—*Asclepiadaceæ*, acrid, emetic (Mudar).

Leaves alternate.

Æstivation valvate or induplicate.—*Solanaceæ*, edible (Potato), diaphoretic (Bitter-Sweet).

Æstivation imbricate.—*Atropaceæ*, poisonous, narcotic, cause dilatation of the pupil (Belladonna, Henbane).

II. Flowers irregular, stamens didynamous, or two.

Ovary four-lobed externally, fruit four achenes.—*Labiatæ*, tonic, stomachic (Mint).

Ovary undivided.

Stems leafless, plants parasitic.—*Orobanchaceæ*, astringent (Broomrape).

Stems leafy, plants not parasitic.

Capsule two-celled.

Seeds attached to placentas by hard, usually hooked processes.—*Acanthaceæ*, emollient (Acanthus).

Seeds without hard or hooked stalks.—*Scrophulariaceæ*, suspicious, sedative (Digitalis).

Capsule one-celled.—*Gesneraceæ*, succulent, fruit eatable (Gesnera).

Sub-class—MONOCHLAMYDEÆ.

A. Angiospermæ, seeds in an ovary.

I. Ovary inferior, or partially so.

1. Flowers in catkins.

Seeds hairy, fruit without a cupula.—*Salicaceæ*, bitter tonic, febrifuge (Willow).

Seeds not hairy.

Fruit with a cupula.—*Cupuliferæ* or *Corylaceæ*, bark astringent (Oak).

Fruit membranaceous, indehiscent.—*Betulaceæ*, astringent (Birch).

Amentiferæ.

2. Flowers not in catkins.
  - Flowers with stamens and pistils.
    - Ovary with a single ovule.—*Chenopodiaceæ*, wholesome, insipid (Spinach).
    - Ovary with more than one ovule.—*Aristolochiaceæ*, tonic, stimulating (Aristolochia).
  - Flowers with stamens only, or with pistils only.—*Begoniaceæ*, astringent, bitter (Begonia).

II. Ovary superior.

1. Flowers with stamens and pistils.
  - Anthers opening by four recurved valves.—*Lauraceæ*, aromatic (Cinnamon).
  - Anthers not opening by recurved valves.
    - Flowers naked or achlamydeous.—*Piperaceæ*, condiments (Pepper), astringent (Matico).
    - Flowers with a double perianth.
      - Stamens placed on lobes of perianth, no stipules.—*Proteaceæ*, fruit sometimes eaten (Avellano).
      - Stamens not placed on lobes of calyx, ochreate stipules.—*Polygonaceæ*, acid (Sorrel), purgative (Rhubarb).
2. Flowers with stamens only, or with pistils only.
  - Carpels more than one united into a solid pistil.
    - Leaves forming pitchers, wood without zones. fruit four-celled.—*Nepenthaceæ*, subacid fluid in pitchers (Pitcher-plant).
    - Leaves not forming pitchers, wood with zones, fruit tricoccous.—*Euphorbiaceæ*, acrid, stimulant, poisonous (Castor oil, Croton oil, Cascarilla).
  - Carpels solitary or separate.
    - Fruit a drupe with an aril, albumen mottled.—*Myristicaceæ*, aromatic (Nutmeg).
    - Fruit a nut without an aril, albumen uniform.—*Urticaceæ*, narcotic, tough fibres (Hop, Hemp).

Suborder : *Moreæ*, eatable fruit (Mulberry).

——— *Artocarpeæ*, milky juice, poisonous (Upas), fruit eatable (Fig and Bread-fruit).

B. Gymnospermæ, seeds naked.

Stem terminated by a single bud, leaves pinnate, with circinate vernation.—*Cycadaceæ*, amylaceous (Cycas).

Stem bearing many buds, leaves simple, not circinate.

Seeds in cones.—*Coniferæ*, turpentine, pitch (Fir, Spruce).

Suborder : *Cupressineæ*, acrid oil (Savin).

Seeds solitary, with a succulent cup-shaped receptacle.—*Taxaceæ*, resinous, leaves and seeds dangerous (Yew).

ANALYSIS OF SOME OF THE ORDERS IN THE CLASS MONOCOTYLEDONES.

Sub-class—PETALOIDEÆ.

A. Flowers complete, having a perianth.

I. Ovary inferior.

1. Veins diverging from midrib.

Monandrous.

Anthers two-celled.—*Zingiberaceæ* or *Scitamineæ*, aromatic, stimulating (Ginger).

Anthers one-celled.—*Marantaceæ*, amylaceous (Arrow-root).

Hexandrous.—*Musaceæ*, fruit nutritious (Banana and Plantain).

2. Veins parallel with the midrib.

Flowers gynandrous.—*Orchidaceæ*, aromatic, mucilaginous (Vanilla, Orchis, Salep).

Flowers not gynandrous.

Albumen mealy, plants scurfy.—*Bromeliaceæ*, acid fruit (Pine Apple).

Albumen horny or fleshy, plants not scurfy.

Triandrous, anthers extrorse.—*Iridaceæ*, aromatic (Orris-root).

Hexandrous, anthers introrse.—*Amaryllidaceæ*, some poisonous (Hæmanthus).

3. Veins netted.—*Dioscoreaceæ*, nauseous, sometimes eatable (Yams).

II. Ovary superior.

1. Veins parallel, not netted.

a. Sepals petaloid.

Flowers on a spadix, seeds solitary.—*Palmæ*, amylaceous, saccharine (Sago, Coco-nut).

Flowers not on a spadix, seeds numerous.

Anthers introrse, styles united.—*Liliaceæ*, bitter, stimulant, purgative (Squill, Onion, Aloes).

Anthers extrorse, styles distinct.—*Melanthaceæ*, cathartic, narcotic, diuretic (Colchicum).

b. Sepals green or scaly.

Carpels separate.—*Alismaceæ*, aquatic plants, acrid (Alisma).

Carpels united.—*Juncaceæ*, used for mats (Rushes).

2. Veins netted.—*Smilaceæ*, demulcent (Sarsaparilla).

B. Flowers incomplete, without any perianth or with a few verticillate scales.

1. Flowers on a spadix.

With stamens only, or with pistils only.

Anthers sessile, vernation convolute.—*Araceæ* or *Aroideæ*, acrid, poisonous, also amylaceous (Arum, Dumb-cane, Portland Sago).

Anthers stalked.

Fruit a fibrous drupe or a berry.—*Pandanaceæ*, seeds edible (Screw Pine).

Fruit dry, anthers clavate with slender filaments.—*Typhaceæ*, astringent, yield starch (Bulrush or Reed-mace).

With stamens and pistils.—*Orontiaceæ* or *Acoraceæ*, aromatic (Sweet-flag), fœtid (Skunk-Cabbage), acrid (Calla).

2. Flowers not on a spadix.
    Terrestrial plants.—*Juncaginaceæ*, styptic (Arrow-grass).
    Aquatic plants.—*Lemnaceæ* or *Pistiaceæ*, acrid (Duckweed).

Sub-class—GLUMIFERÆ.

Stems fistular, sheaths split.—*Gramineæ*, fruit yields flour (Corn), herbage sweet (Sugar-cane).
Stems solid, and sheaths entire.—*Cyperaceæ*, diaphoretic (German Sarza).

ORDERS IN THE CLASS ACOTYLEDONES.

Filices or Ferns.—Astringent, pectoral, some eatable, some anthelmintic (Male Shield Fern).
Musci or Mosses.
Hepaticæ or Liverworts.
Lichenes or Lichens.—Dye (Archil), nutritious (Iceland and Reindeer Moss, and Tripe de Roche).
Fungi or Mushrooms.—Stimulant, nutritious (Mushroom, Truffle), often poisonous (Ergot, Amanita).
Algæ or Sea-weeds.—Nutritious (Irish Moss, Laver, Dulse).

We observe then that there are certain laws of order, according to which plants appear to have been created by God. He indicates this in the first chapter of Genesis,—"God said, Let the earth bring forth grass, the herb yielding seed, and the fruit-tree yielding fruit after his kind, whose seed is in itself." Some have thought that they perceive in this announcement the three great divisions of the natural system which we have just noticed. Whether this view is correct or not, it is evident that there is an orderly method in the vegetable kingdom, and although we may not have yet arrived at a correct and complete knowledge of that method, still we are enabled to see marked evidences of it. By means of the powers of observation and comparison with which it has pleased the Almighty to endow His rational creatures, they are privileged to trace out the doings of Him who worketh all things after the counsel of His own will. There are indubitable marks of alliances in plants. These are obvious even to the ordinary observer of nature, but it is only by the scientific student that the true affinities of the vegetable productions of the globe can be ascertained.

In tracing the relation of plants we have, even in the abortive condition of organs, a means of aiding us in arrangement. The non-development of a stamen gives rise to the want of symmetry in a flower such as Gloxinia or Scrophularia. In its place, however, a small process is found, which may be said to be of no use to the plant itself, but which is of importance in pointing out to us the plan of the Creator. We are entitled to say that the organ is an abortive state of a stamen, because it occupies the exact place where a stamen ought to be, and, moreover, by cultivation it is actually developed at times as a true and perfect stamen. In this case the corolla which was irregular becomes regular, proving that its form is connected in some degree with the state of the staminal whorl. In the natural order Scrophulariaceæ or figworts, we can trace evidently a series of graduated changes, beginning at Verbascum with its regular flower, having 5 divisions of the calyx and corolla and 5 stamens; then going to Pentstemon, with its slightly irregular flowers and 4 stamens, the 5th being seen in an abortive condition; then to Scrophularia or figwort, with a very irregular corolla, and a still more imperfectly developed 5th stamen, in the form of a scale on the corolla, and the stamens of different lengths; then to Digitalis or foxglove with its less irregular flower, and 4 irregular stamens without the rudiment of a 5th; then to Calceolaria, with a remarkable two-lipped corolla, and only 2 stamens; and finally reaching Veronica, with its binary symmetry, and slightly irregular corolla.

The more deeply we study the structure of plants, and the more diligently we compare those belonging to different countries, the more likely are we to arrive at correct views relative to vegetable groups. Great advances have been made in arrangement, but we cannot say that botanists are yet agreed as to the true system of nature. In attempting to ascertain it we must take a comprehensive view of all the plants of the world, and we must know accurately the structure of their organs in all its diversity. The highest powers of mind may thus be engaged in tracing out the handiwork of Him who is wonderful in counsel and excellent in working. Methodical arrangement is conspicuous in God's works. He is a God of order. His plan is perfect, although we may not have attained to the knowledge of it. The discoveries of science are daily adding new means for the attainment of this knowledge, and we may hope for the final development of the plan of the Almighty Architect. But if to our finite powers this attainment is now denied, we may in faith look onward to the time when knowledge shall be perfect, when the believer shall know even as he is known, and when amidst the glories of eternity he will be enabled to scan the doings of Him who created all things, and by whom all things subsist—even the Incarnate Word who laid the foundations of the earth, and whose Spirit revealeth to His people all things, yea, the deep things of God.

For although the glorious work of redemption shall be the theme of praise during the endless ages of eternity, still there seems to be no doubt that He who will create a new earth for His people will enable them to perceive the beauty, order, and harmony of the arrangements, which are shadowed forth in the Sacred Scriptures in the following terms:—"Instead of the thorn shall come up the fir-tree, and instead of the brier shall come up the myrtle-tree" (Isa. lv. 13). "I will plant in the wilderness the cedar, the shittah-tree, and the myrtle, and the oil-tree; I will set in the desert the fir-tree, the pine, and the box-tree together; that they may see, and know, and consider, and understand together, that the hand of the Lord hath done this, and the Holy One of Israel hath created it" (Isa. xli. 19, 20).

CHAPTER IV.

ON THE GEOGRAPHICAL DISTRIBUTION OF PLANTS.

THE nature of the vegetation covering the earth varies according to climate and locality. Plants are fitted for different kinds of soil as well as for different amounts of temperature, light, and moisture. From the Poles to the Equator there is a constant variation in the nature of the flora. Between the Lichens of the Arctic and Antarctic regions and the Palms of the Tropics, there is a series of regulated changes in the number and forms of the members of the vegetable kingdom. The same thing is observed in the vegetation of lofty mountains at the Equator in descending from their summit to their base. There are few spots on which no vegetation whatever can be detected. Among such barren districts may be mentioned the hot, sandy deserts of Africa, and some of the Antarctic islands. In determining the effects of climate on vegetation, our attention is chiefly directed to temperature and moisture,—to the daily, monthly, and annual distribution of heat, and to the amount of rain. The influence of sea and land in great masses, in altering climate, is very marked. The former moderates extreme heat and cold, the latter increases the inequalities of climate. Plants require a certain amount of heat in order to attain their perfect development. This heat is communicated to them directly by the sun and indirectly by the soil. To both of these sources we must look for explaining the phenomena of vegetation. The amount of heat required for the plant to perfect its flowers and fruit may be communicated rapidly or slowly according to the nature of the country in which the plant grows. Thus plants in some regions go through their phases of life speedily, while in others their period of vegetation is protracted.

Some plants have a very wide range, but no flowering plant is an absolute cosmopolite. Some of them extend over more than one-third of the earth's surface. De Candolle enumerates 117 species of this sort, and of these 100 are

British. None appear to compass the whole earth, however wide their extent. The common chickweed (*Stellaria media*), which endures very severe climates, and easily becomes naturalised in temperate regions, is not found at Melville Island nor in Labrador, nor under the equator. Nettles, which generally accompany man, do not support, like him, the extremes of heat and cold. They are wanting in Labrador and Melville Island, as well as in the plains of the torrid zone. Purslane (*Portulaca oleracea*), sowthistle (*Sonchus*), amplexicaul dead-nettle (*Lamium amplexicaule*), goosefoot (*Chenopodium album*), and dog's-tooth grass (*Cynodon Dactylon*), which may be looked upon as universally diffused, do not penetrate into extreme northern climates. The common sowthistle (*Sonchus oleraceus*) is a plant apparently fitted for all climates, but it needs a cultivated soil or rubbish. The number of species which occupy half the globe is very limited. De Candolle gives a list of eighteen. Many of the most widely diffused are aquatic or grow in moist situations. Many plants have been widely diffused by man as furnishing food or materials for manufacture.

While some plants are generally and widely distributed others are confined to particular countries, and are sometimes restricted within narrow limits. One region in the Andes is marked by the occurrence of species of *Bejaria,* another by Cinchona-bark trees. Certain plants belonging to the natural order Polemoniaceæ are peculiar to California. A species of *Disa,* with a large crimson flower, is confined to Table Mountain, growing in abundance on the border of a little streamlet. *Codon Royeni* and *Protea acaulis* are restricted to a few localities at the Cape of Good Hope. The double coco-nut palm is found only on the rocky islets of the Seychelles. Each of the Canary Islands has species peculiar to itself, and this is still more remarkable in the Gallipagos. *Cyperus polystachyus,* a plant of tropical and extra-tropical countries, grows on the mouth of the crater of the extinct volcano of the island of Ischia, and this is the only locality for it in Europe. The Australian pitcher-plant (*Cephalotus follicularis*) is found only in the bays round King George's Sound. The species of pitcher-plant (*Nepenthes*), are very local; each tropical island, in the area occupied by the genus, has its peculiar species. *Clianthus puniceus* of New Zealand is very limited in its range in that country. St Helena contains many species and even arborescent genera which are not only found nowhere else, but which are confined to very small areas on the island; the tree-fern (*Dicksonia arborescens*) occurs only on Diana's Peak in the centre of the island. *Aira antarctica,* a species of grass, the most southern flowering plant known, is restricted to the antarctic islands. Captain Cook's Cabbage (*Pringlea antiscorbutica*), grows only on Kerguelen's Land, an island which is the remotest of any from a continent. Out of 133 species found on Norfolk Island 61 are peculiar to that island; and the island of Tristan da Cunha contains 32 species of flowering plants of which 26 have been found nowhere else.

Some families of plants, on account of their form, aspect and locality, particularly engage the attention not of the botanist only but of every observer of nature. They are called Physiognomic plants. Their diffusion is connected not merely with the soil but with various external circumstances of climate. In illustration of physiognomic plants De Vriese refers to boundless tracts in Europe overgrown with the common heather (*Calluna vulgaris*); fens covered with species of the moss called *Sphagnum;* pine woods, with here a moss vegetation, there the blaeberry (*Vaccinium Myr-*

tillus), and in another place the Eagle-fern (*Pteris aquilina*); northerly regions, in which many square miles are covered with the rein-deer-moss (*Cladonia rangiferina*), and in these regions may be seen the dwarf birch (*Betula nana*) clustering in myriads over a small space; palm-forms chiefly in Mexico and South America; ferns, specially tree-ferns, in the East Indian Archipelago, in Java, and the Philippine islands; Rhizophoras or mangroves at the mouths of great tropical rivers; and screw-pines, another tropical group, remarkable by the development of their stems and aerial roots. These plants give an idea of social growth.*

Wherever circumstances are compatible with vegetable existence, there we find plants arise. The solitary island in the midst of the ocean, as well as the extended continent; the parched desert, and the fertile plain; the deep cavern, and the lofty mountain; the stagnant pool, and the meandering stream, have each their peculiar vegetation. Even the sides of the volcano are covered with flowers; and the geysers of Iceland, and the hot-springs of Switzerland and Arabia, are not without their vegetable productions. The ever-sounding and mysterious deep hides in its bosom many a plant no less conspicuous for beauty and variety of form than splendour of colour, and admirably fitted for the place it is designed to occupy. On the sands of the torrid zone, the eye of the traveller is occasionally refreshed by the appearance of a few succulent plants which are enabled to thrive amidst these arid regions; and in the realms of perpetual snow which surround the poles, attention is arrested by the prospect of fields of red snow, which owe their existence in part to plants of a microscopic nature (*Protococcus nivalis*). Thus it is that vegetation is spread over all quarters of the globe, and is wisely adapted to all varieties of climate.

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* Hooker's Kew Journal, vi., p. 257.

"The carpet of flowers and of verdure," Humboldt remarks, "spread over the naked crust of our planet, is unequally woven; it is thicker where the sun rises high in the ever-cloudless heavens, and thinner towards the poles—in the less happy climes where returning frosts often destroy the opening buds of spring, or the ripening fruits of autumn. Everywhere, however, man finds some plants to minister to his support and enjoyment." Those who view nature with a comprehensive glance, he continues, "see, from the poles to the equator, organic life and vigour gradually augment with the augmentation of vivifying heat. But in the course of this progressive increase, there are reserved to each zone its own peculiar beauties: to the tropics, variety and grandeur of vegetable forms; to the north, the aspect of its meadows and green pastures, and the periodic awakening of nature at the first breath of the mild air of spring. Each zone, besides its own peculiar advantages, has its own distinctive character—each region of the earth has a natural physiognomy peculiar to itself. The idea indicated by the painter, by expressions such as *Swiss nature, Italian sky*, etc., rests on a partial perception of this local character in the aspect of nature. The azure of the sky, the lights and shadows, the haze resting in the distance, the form of animals, the succulency of the plants and herbage, the brightness of the foliage, the outline of the mountains, are all elements which determine the total impression characteristic of each district or region."

While the Creator has bountifully distributed His floral gifts in every quarter of the globe, it is in warm climates that vegetation displays its most majestic forms. There we meet with the Baobab, one of the oldest living monuments of the globe, with its trunk thirty feet in diameter, and its foliage forming a mass of enormous dimensions (fig. 189, p. 253). There we find the branching Banyan, with its numerous stems (fig. 45, p. 63), thus described by Southey:—

> “ 'Twas a fair scene wherein they stood,
> A green and sunny glade amid the wood,
> And in the midst an aged Banyan grew.
> It was a goodly sight to see
> That venerable tree;
> For o'er the lawn, irregularly spread,
> Fifty straight columns propt its lofty head;
> And many a long depending shoot,
> Seeking to strike its root,
> Straight like a plummet grew towards the ground.”

There grow the palms (figs. 71, 72, p. 92), plantains, and bananas (fig. 23, p. 32), with their large leaves and abundant fruit. There the air-plants (fig. 145, p. 216), enliven the trunks of the gigantic trees, and climbing plants develop their gorgeous blossoms. There the richest fruits and spices are produced, flowers of the most varied hues unfold themselves, and the air is perfumed with the most fragrant and balmy odours. There the Cymbidium and fragrant Vanilla enliven the trunks of the Anacardiums and the gigantic fig-trees. The fresh verdure of the Pothos leaves and of the

Dracontias, contrasts with the many-coloured flowers of the Orchis (fig. 145, p. 216); climbing Bauhinias, passion-flowers, and yellow-flowering Banisterias, twine round the trunks of the forest trees. Delicate blossoms spring from the roots of the chocolate tree (fig. 232), and from the thick and rough bark of the calabash and Gustavia. In the midst of the profusion of flowers and fruits, and in the luxuriant intertwining of the climbing plants, the naturalist often finds it difficult to discover to what stem the different leaves and flowers really belong. Dr W. H. Campbell, in giving an account of the vegetation of the forests of Demerara, writes,—"The luxuriance of the vegetation surpassed everything you could conceive. Every inch of ground was occupied, and the eye looked in vain for any spot which nature had left unclothed and less bountifully supplied than that immediately around you. Indeed, it seemed as if there was one dire scramble for existence, and that each was striving with

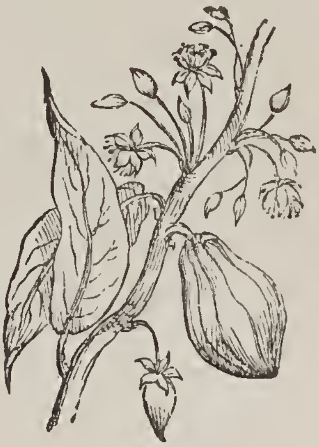

Fig. 232.

Fig. 232.—Chocolate tree (*Theobroma Cacao*). It yields Cacao beans, from which chocolate is prepared. These beans are the seeds contained in the large fruit which is shown in the figure.

might and main to reach the upper light and air, lest being left behind in the race, the forfeiture of life should be the penalty."

In tropical regions, the luxuriance of the vegetation is not more remarkable than the rapidity of its growth. After the dry season in the Brazilian plains, and when the first few showers have fallen, the annual grasses shoot forth their blades, the trees burst into leaf and blossom, and the perennial herbaceous plants, which during drought were apparently destroyed, throw up their flowering stems with astonishing vigour. In the neighbourhood of the Cape of Good Hope, after the cessation of the rainy season, the earth becomes parched, vegetation languishes, and the leaves wither and die, so that all appearance of verdure and life is lost, till on the first fall of rain it suddenly revives, and the plains become immediately covered with a countless variety of blossoms and flowers.

As we proceed from warm regions towards the poles, we find that as the light and heat diminish, vegetation is checked in the same proportion. At every step of our progress we change the vegetable group. From the hottest climates we pass in succession through those of the pine-apple, sugar-cane (fig. 233), coffee (fig. 234), date (fig. 235), cotton, citron, and olive, till we reach the region of the vine.

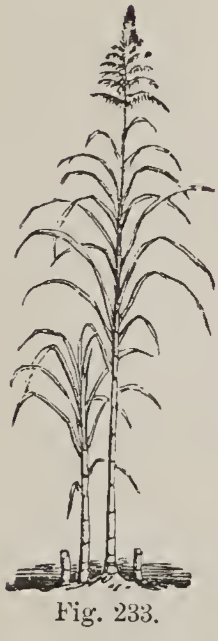
Fig. 233.

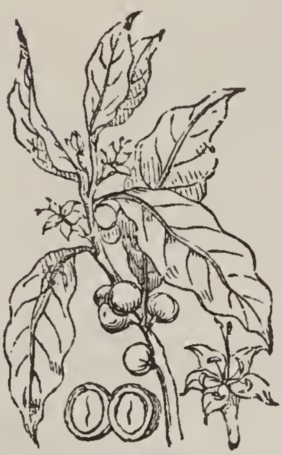
Fig. 234.

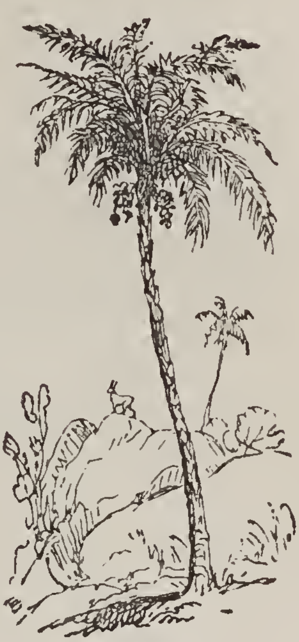
Fig. 235.

The spices and fruits of equatorial Asia are succeeded, in the thickets to the east of the Caspian, by the apricot, the peach, and the walnut. In the southern regions of Europe, the dwarf palm, the cypress, and the cork tree (fig. 236), make their appearance; the orange and lemon perfume the air with their blossoms, and the myrtle and pomegranate grow wild

Fig. 233.—Sugar-Cane (*Saccharum officinarum*), a large tropical grass.

Fig. 234.—Coffee Tree (*Coffea arabica*), with its succulent berries, containing coffee seeds.

Fig. 235.—Date Palm (*Phœnix dactylifera*). The Palm mentioned in the Bible. It yields the fruit called dates, which hang in clusters from the top of the stem, as seen in the figure.

among the rocks. Again, when we pass the Alps, we find the vegetation of northern climates; forests of oak, beech, and elm adorn the landscape, and are ultimately replaced by various species of hazel, fir (fig. 237), and birch.

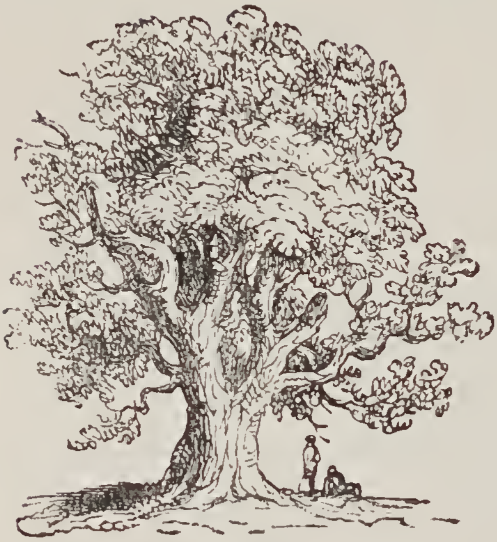

Fig. 236.

The vegetation of cold regions does not assume any of the grandeur and luxuriance which we observe in the tropics. As we approach the shores of the Arctic Ocean, the trees become few and diminutive. In Siberia, their thin and distorted trunks are clad, as it were, with a fur-like covering of lichens, which occupy the place of the orchids of warm

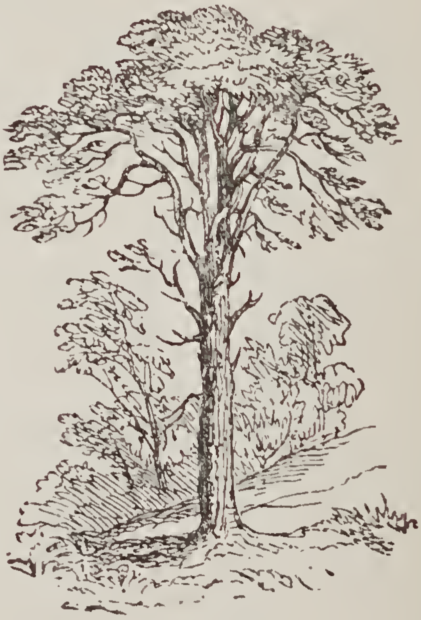

Fig. 237.

Fig. 236.—Cork Tree (*Quercus Suber*) found in the south of Europe. Its outer bark furnishes the cellular substance called Cork.

Fig. 237.—Scotch Fir (*Pinus sylvestris*), a tree of cold climates.

regions. Further north, the only shrub we find is the dwarf birch; and a little beyond the 70th degree not a tree or shrub is to be seen. In Finmark, the Scotch fir, the hoary alder, the aspen, and the rowan tree, attain to lat. 70°, while the common and the dwarf birch and the Lapland willow extend 40 minutes further north, and are the only woody plants found in the neighbourhood of Hammerfest. Spitzbergen is said to produce only one plant possessed of a proper woody stem; mosses form more than a quarter of the whole vegetation of Melville Island, and the soil of New South Shetland is covered with specks of mosses struggling for existence. Dr Hooker states that on one of the antarctic islands he gathered the *ghosts* of eighteen cryptogamic plants, chiefly mosses and lichens; and that there appeared no trace whatever of flowering plants. Even in those regions where snow lies upon the ground during the greater part of the year, the Creator calls into existence peculiar tribes of plants, which are enabled, during the short summer of such inhospitable climes, to pass through their various periods of sprouting, flowering, and fruiting. The plants, so to speak, seem to fear lest they should not be able to perfect their seeds before the cold and darkness arrest their growth. Though there are regions as Melville Island in which the mean temperature is below zero of Fahr., still it is established that nowhere in the northern hemisphere does the snow-line attain the level of the sea. This depends on the intensity of the summer-heat during the period of perpetual day, thawing the soil, though only to a small depth, and allowing a brief vegetation to spring up suited for the support of arctic animals.

The adaptation of plants to different climates is a subject well fitted to call forth our admiration. The succulent plant (fig. 238), well provided with stores of fluid, and in which evaporation takes place with the greatest difficulty, is made to grow in the parched and thirsty district. In the deserts of the East, and the sandy plains of Arabia, where the heat from the earth dissipates the passing cloud, which hastens, as it were, to shed its refreshing moisture on

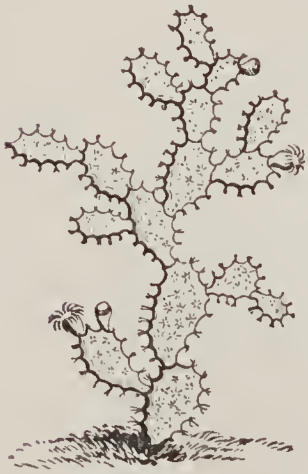

Fig. 238.

Fig. 238.—Prickly Pear or Indian Fig (*Opuntia vulgaris*). On a plant of this kind (*Opuntia cochinillifera*) the cochineal insect feeds;—the female insects being collected and dried to furnish the dye as imported.

a more grateful spot, where no water issues from a spring or falls from on high, there the water-melon grows, offering a delicious draught to the traveller. On the Pampas of South America the Cactus, with its juicy stems, like a vegetable fountain, refreshes the wild herds which roam over the plains, and which instinctively tear off the formidable external prickles of the plant in order that they may reach the succulent interior (fig. 239). The Ravenala, or traveller's tree, furnishes from the base of its leaves a supply of water to the traveller in Madagascar. The palm develops its umbrageous foliage in those regions where it is most required for shelter from the heat of the sun. The bread-fruit (fig. 240),

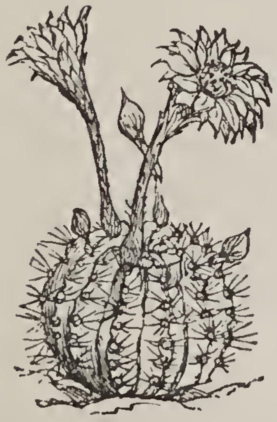

Fig. 239.

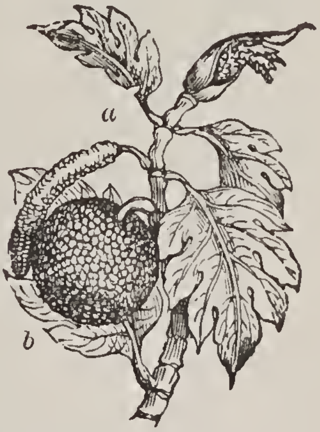

Fig. 240.

Fig. 239.—Tube-flowered Spine-Cactus (*Echinocactus tubiflorus*), with a peculiar succulent stem whence the flowers arise. The prickles on the outside are torn off by the cattle in order to get the fluid inside.

Fig. 240.—Bread-fruit tree (*Artocarpus incisa*), with a cluster of

banana (fig. 23, p. 32), plantain, mango, and coco-nut (fig. 2 *a*, p. 9), are produced in abundance in those climates where they are best fitted for the support and wellbeing of the inhabitants. In temperate climes, where animal food is more essential to existence, we meet with the grassy herbage and the green pastures adapted for the food of cattle; while in arctic regions, the lichen on which the reindeer feeds (fig. 241), thrives at a temperature sufficient to kill most other plants.

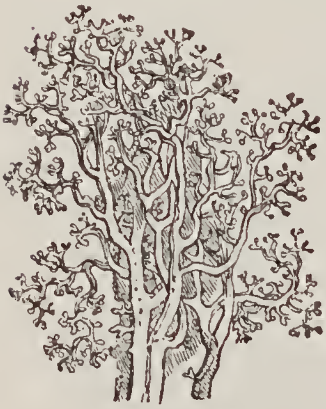

Fig. 241.

A lofty mountain at the equator exhibits, as it were, an epitome of what takes place, on a grander scale, over the whole globe. It presents to us different climates, and at the same time different zones or belts of vegetation. In the South American plains we meet with palms (fig. 2 *a*, p. 9), and bananas (fig. 23, p. 32), in the greatest luxuriance; as we ascend the Andes we come to tree-ferns (fig. 242), then to the Peruvian-

staminiferous flowers *a* forming a spike, and a large globular fruit *b* composed of numerous flowers united. It supplies nourishing food in the South Sea Islands.

Fig. 241.—Reindeer moss (*Cladonia rangiferina*), the lichen on which the reindeer feeds in cold countries.

bark trees (fig. 243); passing through the

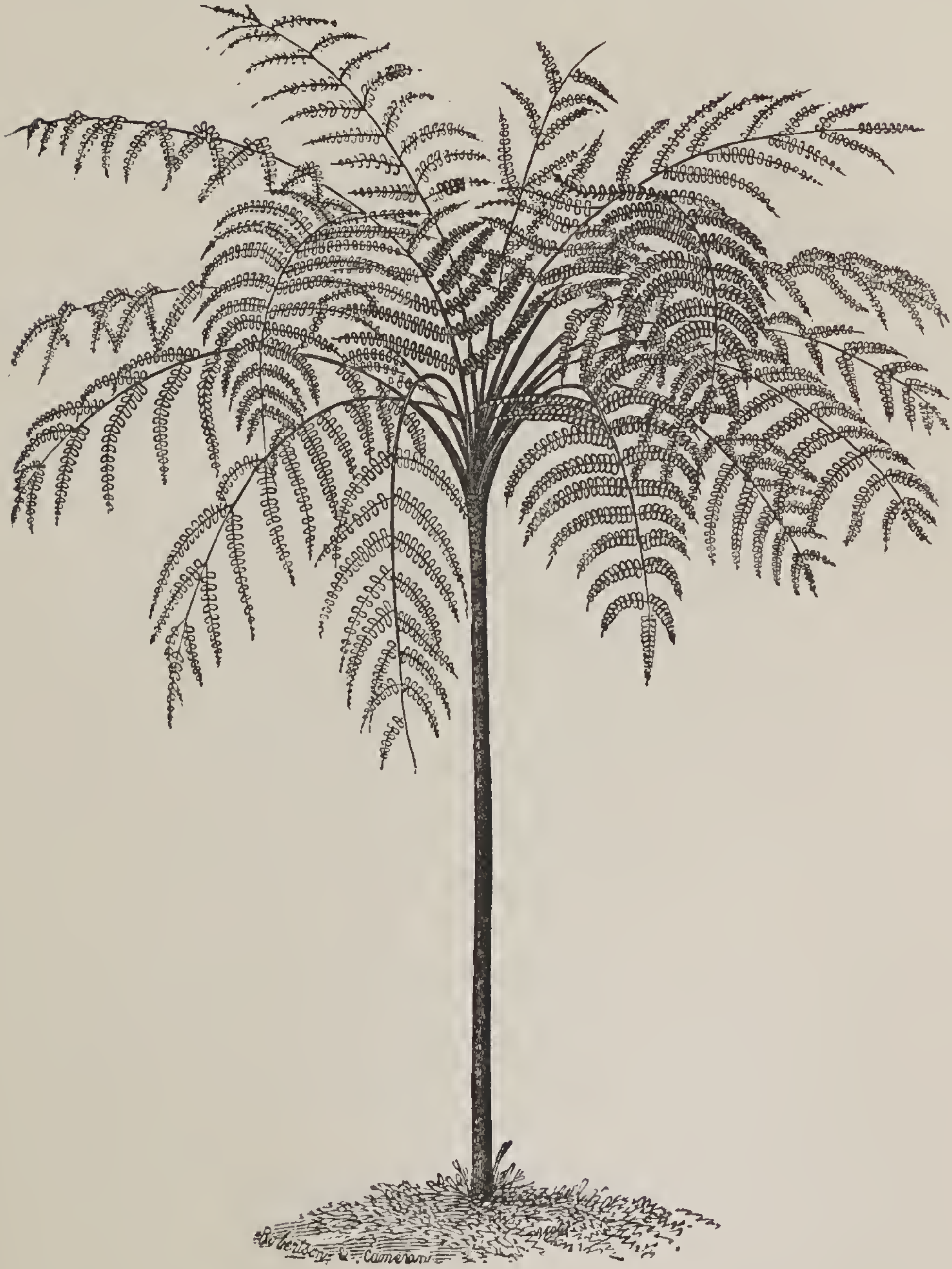

Fig. 242.

Fig. 242.—Tree-fern with its slender cylindrical trunk, and crown of

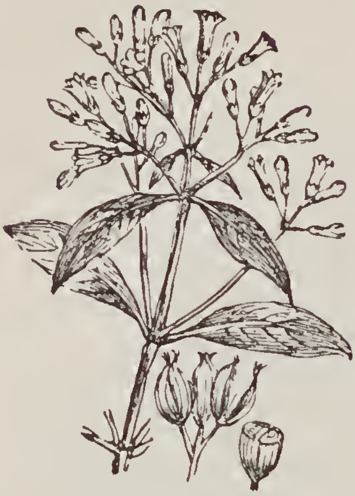

Fig. 243.

woody region, we arrive at a shrubby zone, succeeded by grassy meadows, and finally we tread on mosses and lichens, which are limited only by the line of perpetual snow. In fig. 244 a representation is given of the zones of vegetation on a tropical mountain. No. 1 is the region of palms and bananas, which is 3000 or 4000 feet above the level of the sea, the temperature ranging from 81° to 71°; No. 2, the region of tree-ferns, reaching to about 5000 feet, mean temperature 66°; No. 3 indicates the limit of the vine, in lat. 16° 24′ S., at about 7000 feet; No. 4, the limit of great trees, mean temperature being 61°; No. 5, region of cinchona-bark trees, extending to 9000 or 10,000 feet on the Andes; No. 6, shrubby region, marked on the Andes by Bejarias at about 10,000 feet; No. 7, region of grasses; No. 8, region of lichens and snow line, at about 15,000 or 16,000 feet. In the Alps of Europe we have the region of the vine ex-

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elegant drooping fronds, on which the fructification is produced. The stem is acrogenous, increasing by additions to its summit.

Fig. 243.—Peruvian-Bark tree (*Cinchona Calisaya*), found on the Andes at the height of 9000 feet above the level of the sea.

tending to 1700 feet; to this succeeds the zone of the chestnut, which extends to 2500 feet; the zone of the beech, and of the higher dicotyledonous trees, reaches from 2500 to 4000 feet; we then come to the subalpine region, the zone of conifers, extending to about 6000 feet, in which are found the Scotch fir, the

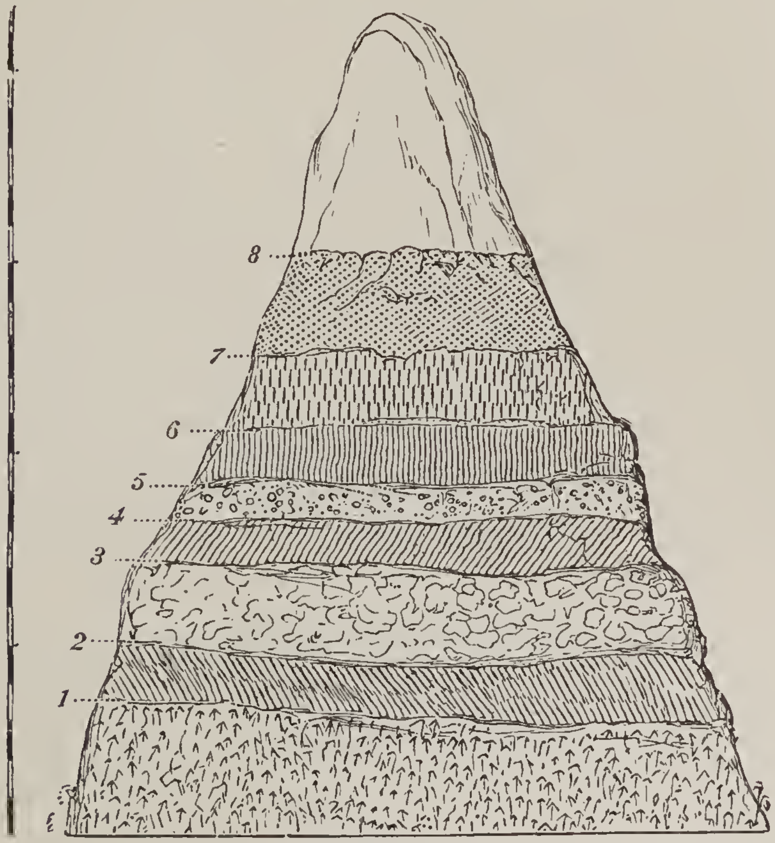

Fig. 244.

Fig. 244.—Plan of a mountain in the Torrid Zone, with a scale indicating the number of feet, each division of the scale being equal to 1000 feet. 1. Region of palms. 2. Region of tree-ferns. 3. Region of vine. 4. Limit of great trees. 5. Region of Cinchona or Peruvian-bark. 6. Shrubby region (Bejarias). 7. Region of grasses and some hairy plants, as Culcitium. 8. Region of lichens, ending in snow line.

spruce, the larch, and the Siberian pine, along with certain alpine forms of herbaceous plants; next comes the alpine region, or the zone of shrubs, extending to 7000 feet, characterised by *Rhododendron hirsutum* and *R. ferrugineum*, which represent the Bejarias of the Andes; finally, we reach the subnival region, extending to 8500 feet, and comprehending the part between the limit of shrubs and the snow-line, where we meet with numerous species of Ranunculus, Draba, Saxifrage, Gentian, Primrose, Poa, etc. On some of the Alps we find flowering plants reaching to the height of between 10,000 and 11,000 feet or more.

On ascending lofty mountains in Britain, there is a marked variation in the nature of the vegetation. On Ben-muich-Dhui, which attains an elevation of upwards of 4000 feet, Watson gives a list of the species observed in succession. On leaving the plants of the low country we find Myrica Gale, extending on this mountain to 1400 feet, and in succession we come to the upper limits of the following species:—Erica cinerea, Pinus sylvestris, Carex pauciflora, Pedicularis sylvatica, at 1838 feet; Tofieldia palustris, Erica Tetralix, at 2370 feet; Arctostaphylos Uva-Ursi, Thalictrum alpinum, Vaccinium Vitis-Idæa, Hieracium alpinum, Juniperus communis *var.* nana, at 2660 feet; Potentilla Tormentilla, Calluna vulgaris, at 2690 feet; Azalea procumbens, Armeria maritima, Cochlearia gröenlandica, Arabis petræa, Rubus Chamæmorus, Epilobium alpinum, E. angustifolium, Vaccinium uliginosum, Sibbaldia procumbens, Saxifraga stellaris, Alchemilla alpina, Empetrum nigrum, Juncus trifidus, Gnaphalium supinum; and on the summit (above 4000 feet) Silene acaulis, Carex rigida, Luzula arcuata, L. spicata, and Salix herbacea.

Considering British plants in climatic or ascending zones, they are divided by Watson into—

I. AGRARIAN REGION—limited generally by the Pteris aquilina, and indicating the region of Corn cultivation. In the Highlands it may be said to extend as high at least as 1200 feet.

It is subdivided into three zones:—

1. *Infer-agrarian Zone*—embracing all the country southward from the Dee and Humber, except the mountainous parts of Wales, and the higher hills and moors in the provinces of the Severn and Peninsula (including Gloucester, Worcester, Warwick, Stafford, Hereford, Monmouth, Cornwall, Devon, and Somerset). Some of the peculiar species are Clematis Vitalba, Rubia peregrina, Cyperus longus, Erica ciliaris, Sibthorpia europæa, and Scilla autumnalis.
2. *Mid-agrarian Zone*—all the low grounds, clear from the mountains, situate between the en-

trance of the Clyde and Tay on the north, and those of the Humber and Dee on the south, also probably a narrow coast-line of the East Highlands, extending from Perth to Aberdeen, and possibly even to Inverness. Also a narrow belt extending round the hills of Wales. Rhamnus catharticus and Frangula, Tamus communis, Bryonia dioica, Acer campestre, Ulex nanus, Viburnum Lantana, Euonymus europæus, and Cornus sanguinea, occur in this zone, but are not restricted to it. There is no Clematis.

3. *Super-agrarian Zone*—coast-line and low plains and moors in the north and north-west of Scotland, where alpine plants descend to the sea-shore; such as Thalictrum alpinum, Draba incana, Saxifraga oppositifolia, Arctostaphylos alpina, and Dryas octopetala. Also other parts where the elevation of the ground leads to the production of the same species, or of such plants as Arctostaphylos Uva-Ursi, Saxifraga stellaris, Alchemilla alpina, Tofieldia palustris, Juncus triglumis. Also tracts of slight elevation in the proximity of high mountains, upon which a corresponding flora prevails. At its lower limits appear Ilex, Corylus, Quercus, Fraxinus, Lonicera, Cratægus, and fruticose Rubi.

II. Arctic Region—characterised by the absence of Corn cultivation.

1. *Infer-arctic Zone*—this has its terminal line at the limit of Erica Tetralix.
2. *Mid-arctic Zone*—space above the limit of Erica Tetralix, and within or below that of Calluna vulgaris. In this zone most of the rare alpine plants are found, such as Saxifraga nivalis, Gentiana nivalis, Erigeron alpinus, Astragalus

alpinus, Veronica alpina, Alopecurus alpinus, etc.

3. *Super-arctic Zone*—above the limit of Calluna, characterised by Saxifraga cernua and rivularis, and Luzula arcuata.

These six climatic zones are thus presented in a tabular form :

I. AGRARIAN REGION.

1. *Infer-agrarian Zone*—Clematis, Rubia, Cyperus longus.
2. *Mid-agrarian Zone*—Rhamnus catharticus without Clematis.
3 *Super-agrarian Zone*—Pteris aquilina without Rhamnus, etc.

II. ARCTIC REGION.

4. *Infer-arctic Zone*—Erica Tetralix without Pteris.
5. *Mid-arctic Zone*—Calluna vulgaris without Erica.
6. *Super-arctic Zone*—Salix herbacea without Calluna.

In order that this general distribution of plants over the surface of the globe may be secured, many of them are provided with a large number of reproductive germs or seeds. In the case of the lower tribes of plants, as mushrooms, puff-balls, etc., the number is almost incredible. In a single plant of this tribe, Fries ascertained the existence of ten millions, so minute as to be scarcely visible, often resembling thin smoke, and so subtile that it is difficult to conceive a place from which they could be excluded. The decay of the higher plants furnishes nourishment for thousands of these mushroom-like tribes (fig. 205, p. 274), and the trunk of a dead tree will give rise to millions. Bread cannot be kept for many days without becoming covered with blue mould, composed of myriads of minute but perfect plants of this description (fig. 5, p. 10). Even in the higher classes of plants, we meet with remarkable examples in this respect, some species producing upwards of 50,000 seeds, as already noticed at p. 245.

In order that seeds may be scattered, some of them are provided with hairy and winged appendages, as cotton and pine seeds, and are thus wafted by the winds to a great distance. Others are dispersed by the agency of water. The mountain stream washes down to the valley the seeds which may accidentally fall into it, or which it may happen to sweep from its banks when it suddenly overflows them. The broad and majestic river, winding along the extensive plain, and traversing the continents of the world, conveys, to the distance of many hundreds of miles, the seeds which may have vegetated at its source. The influence of aqueous agents is also remarkably displayed in causing seed-vessels to open and scatter the seeds in a spot fit for germination. Thus, the plant called Rose of Jericho (*Anastatica hierochuntina*) becomes dried up like a ball, and is tossed about by the wind until it comes into contact with water, when its small pods open, and the seeds are scattered; and a species of fig-marigold in Africa opens its seed-vessel when moisture is applied (fig. 245, and figs. 186, 187, p. 244).

Seeds also are enabled, in many cases, to retain their vitality long, so that they can vegetate even after being kept for many years, and exposed to various vicissitudes. The coco-nut, supported on the waters of the Pacific by means of the buoyant mass of fibrous covering which surrounds it, is said to have been wafted for 1800 miles on the ocean, with its germinating properties unimpaired. It lands on some island or coral-reef which is as yet unclothed with

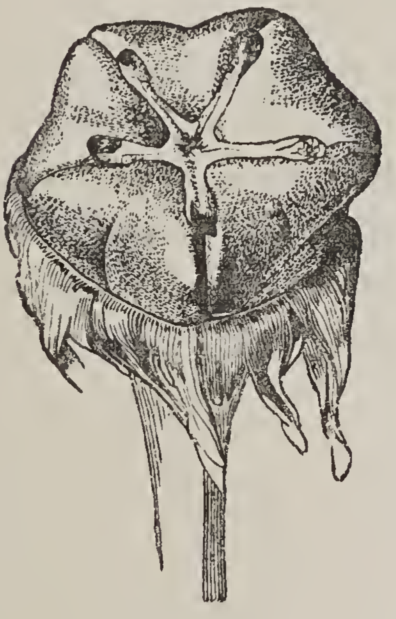

Fig. 245.

Fig. 245.—Seed-vessel of a Mesembryanthemum or Fig-Marigold, which, when ripe, spreads open in five pieces, so as to scatter the seeds. When the ripe seed-vessel is moistened, the opening takes place very speedily.

vegetation, but in the progress of years is to present a green spot in the waste of water where the birds of song shall find shelter, and man shall come to eat the fruits of the land.

> " With such a liberal hand has Nature flung
> Their seeds abroad, blown them about in winds,
> Innumerous mix'd them with the nursing mould,
> The moistening current, and prolific rain."

It has been justly remarked, " Innumerable are the means which the Great Creator employs in spreading fertility, from the gentle summer wind which ripples the water, to the storm which lashes the waves into fury; from the humble and unintentional ministry of the fowl of the air, to the thoughtful plan, and unwearied pursuit of it, which characterise the works of His great masterpiece, man."

CHAPTER V.

RELATION WHICH BOTANY BEARS TO VARIOUS DEPARTMENTS OF SCIENCE AND ART.

From what has been already stated, it may be seen that the science of Botany, when prosecuted for its own sake, is well worthy of attention. It enables us to view the vegetable creation in a very different light from that in which we are apt to regard it. It leads us to contemplate even the commonest weed with sentiments of admiration and wonder; and it forces upon our attention the important lesson of our Lord, that if God so clothe the grass of the field, which to-day is, and to-morrow is cast into the oven, shall He not much more clothe us? (Matt. vi. 30).

We see that many spiritual things are illustrated in the Bible by similitudes taken from natural things. Thus, in the thirteenth chapter of Matthew illustrations are taken from seed, tares, mustard seed, leaven, treasure in a field, a pearl, and a net. Trees, and other creatures of God's providence, speak to us of the attributes and perfection of God. The invisible things of God are clearly seen, being understood by the things that are made, even His eternal power and Godhead (Rom. i. 20). All His works praise Him (see Ps. cxlv. 10, and Ps. cxlviii.); they all speak a distinct language, they all have a voice to which man ought to listen.

In studying the works of God, it is not only necessary to study them in detail, in order to discover their individual beauties, but also in relation to each other as parts of a perfect whole. Each department of natural science has a bearing on the others. Animals and plants are intimately connected, and both of them must be viewed in connection with the inorganic matter of the globe. A naturalist must take a comprehensive grasp of the productions of the globe if he wishes to have a correct view of the system of nature. The different kingdoms of nature, and the different departments of science, pass into each other by insensible gradation. A labourer in one field of science cannot say to the labourer in another, I have no need of thee. Like the members of the body, they are knit together to form one harmonious whole, and their individual efforts are all directed to the same great end. The student of inanimate creation, when he examines the composition of the mineral matters around him, supplies to the student of living nature information on which to found his researches; and the latter, in his turn, furnishes data by which the former determines epochs in the history of the earth's crust. By the researches of the chemist, much has been done to promote the progress of animal and vegetable physiology, and the study of the functions of living beings; and to the labours of the zoologist and botanist, the science of geology is indebted for its most important advances. It is therefore necessary that the student of natural history should not confine his attention to mere isolated portions of creation, but should study the harmonies of all parts of it.

I.—BEARINGS OF BOTANY ON GEOLOGY.

Botany has an important relation to Geology. It enables the geological inquirer to ascertain the nature of the plants which are found imbedded in various rocks, and furnishes him with the means of ascertaining the mode in which these rocks were formed, and the state of the globe at the epoch when they were deposited. "Geology," says Professor Phillips, "would never perhaps have escaped from the domain of empiricism and conjecture, but for the innumerable testimonies of elapsed periods and perished creations which the stratified rocks of the globe present in the remains of ancient plants and animals. So many important questions concerning their nature, circumstances of existence, and mode of inhumation in the rocks, have been suggested by these interesting remains; and the natural sciences have received so powerful an impulse, and been directed with such great success to the solution of problems concerning the past history of the earth, that we scarcely feel disposed to dissent from the opinion, that without fossil zoology and botany there would have been no true geology."

In studying the department of Fossil Botany, attention must be paid not merely to external forms, but also to minute structure. In many of the fossil-plants, the cells and vessels which enter into their composition may be detected by the microscope. Mr William Nicol of Edinburgh was the first to make those sections of fossil-woods which have contributed so much to the advance of our knowledge. In many of the trees found in the sandstone near Edinburgh, as at Craigleith and Granton, distinct disc-bearing woody fibres (fig. 246, also figs. 61, 62, 63, p. 79) have been seen, plainly indicating, along with other characters, that they belong to the cone-bearing tribe, and more especially that they are allied to the Australian Altingias, as represented in fig. 64, p. 80. The presence of vessels with ladder-like bars on their walls (fig. 217, p. 297), have led to the determination of stems of ferns. Besides the elementary tissues and the general forms of plants, it is necessary that the geologist should attend to the scars left by the removal of leaves, to the markings on the bark, and to the character of the fruit, for on all these points the knowledge of fossil-plants depends. There must also be combined with all this a correct idea of the nature of plants as regards the localities and climates in which they grow. There must be the means of distinguishing between plants of salt and those of fresh water, between plants of marshes and those of dry land, between plants of estuaries

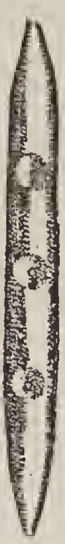

Fig. 246.

Fig. 246.—Woody tube of a coniferous plant, showing rounded disc-like markings. These are seen in many fossil-woods. The punctations are often in double rows, and alternate.

and those of mountains, between plants of warm and those of cold climates. On such facts as these, the determinations of the geologist are founded.

"In the beginning God created the heavens and the earth" (Gen. i. 1); but when *the beginning* was, we know not. No information is given in the Bible as to the state of the globe before the ushering in of its present condition, when "it was without form, and void, and darkness was upon the face of the deep." It only tells us of God's work during six days, and His rest on the seventh. There are, however, indications in the crust of the earth which prove that it has undergone various changes during the time that it was being prepared by the Almighty for the habitation of man. Not the least important data on which these conclusions are based are the presence of fossil-plants of various kinds, and in different rocks.

The vegetation which covered the earth has been altered in its character at different geological epochs. All the plants which have been discovered in a fossil state may be referred more or less evidently to the great divisions of the vegetable kingdom of the present day—the dicotyledons, monocotyledons, and acotyledons. The farther we go back in geological epochs, the more do the species of plants differ from those of the present day. In the most ancient times, it appears that the prevailing vegetation was that of plants allied to ferns; next comes a period when plants resembling the cone-bearers of the present day had the ascendency; and finally, we reach the epoch when plants like our ordinary monocotyledons and dicotyledons predominated. There seems to be thus engraven on the rocks a confirmation of the correctness of our great divisions of the vegetable kingdom. These fossil-plants speak to us clearly in regard to the grand plan of vegetable creation. It is curious to observe that the plants of the early epochs appear to have been those which are not specially adapted for the wants of man, either as regards his nourishment or his enjoyment. They are not fruit trees, nor are they plants producing showy and odoriferous flowers. The colours of the ferns and gymnosperms are of a sombre hue. It is only when we come near to the epoch when man appears that we meet with orders of plants representing those of the present day, which by their products tend to regale the senses of man. The tribes to which such fruits as apples, pears, and cereal grains, or such fragrant plants as mint and lavender belong only occur in the later epoch. There seems to have been a special adaptation for the wants of man when the latest changes took place in the globe,—a preparation for the enjoyments of man who was created in the image of God, and to whom the Almighty Creator gave for meat, every herb yielding seed, such as monocotyledonous cereal grains, and every tree in which is the fruit of a tree bearing seed, or dicotyledonous fruit trees.

In all the phenomena connected with the different fossil floras, there is no evidence of what some have called a progressive development;—there is nothing to favour the idea that species have risen in the scale by being transmuted into others. Those who have enunciated these sentiments, have proceeded upon a bad foundation. Their so-called facts have been mere illusions of the imagination. Thus they support their conclusions by stating that oats may be converted into rye by a constant process of pruning. This so-called fact however, is a mere fiction of their own coining, and is not corroborated by any botanist. There seems to be a capacity in species to accommodate themselves to a certain extent to a change of external circumstances. Thus changes in appearance and structure arise, some of which are capable of being transmitted to the offspring. These changes or variations, however, are not indefinite, but are regulated by certain fixed laws. There cannot be indefinite divergence from the original type; and the extreme limit of possible variation may usually be reached in a short period of time. Species have a real existence in nature, and there is no transmutation from one to another.

" On the hypothesis of *transmutation,* in order to account for the seeming adaptation of the endowments of animals to their wants, it is maintained that the endowments are the result of the wants; and that the most striking attributes of animals, those which apparently imply most clearly the providing skill of their Creator, have been brought forth by the long-repeated efforts of the creatures to attain the object of their desires. Thus animals, it is said, with the highest endowments have been gradually developed from ancestral forms of the most limited organisation: thus fish, birds, and beasts have grown from small gelatinous bodies, possessing some obscure principle of life and the capacity of development: and thus man himself, with all his intellectual and moral, as well as physical privileges, has been derived from some creature of the ape or baboon tribe, urged by a constant tendency to improve, or at least to alter his condition. Every part of the scheme is extremely arbitrary. The capacity for change, and of being influenced by external circumstances, such as we really find it in nature, and therefore such as in science we must represent it, is a tendency not to improve, but to deteriorate. When species are modified by external causes, they usually degenerate, and do not advance; and there is no instance of a species acquiring an entirely new sense, faculty, or organ in addition to or in place of what it had before. Hence, on a full consideration of the whole subject, the conclusions to which we arrive are, that not only is the doctrine of transmutation of species in itself disproved by the best physiological reasonings, but the additional assumptions which are requisite to enable its advocates to apply it to the explanation of the geological and other phenomena of the earth are altogether gratuitous and fantastical." An able refutation of these erroneous views, and a full exposition of their tendency to pervert truth, is given by the late Hugh Miller, in his excellent work, entitled "The Footprints of the Creator." *

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* See also Whewell's Indications of the Creator, and Sedgwick's Discourse on the Studies of the University of Cambridge.

Mr Pearson remarks,—"The theory of progressive development attempts to explain how the earth was peopled as well as how it was formed. It includes within its sweep both the animate and the inanimate phenomena of the universe. It would not only evolve from a universal fire-mist, and by the exclusive operation of physical law, all the forms which matter has assumed, but it would trace the whole organised system in a regularly advancing series, up from an infusorial point to the noblest being, *man.* The language of a chief philosopher of the school (Oken) is, 'No organism is, nor ever has one been created which is not microscopic. Man has not been created, but developed.' 'We call in question,' says another author of the same school ('Vestiges'), 'not merely the simple idea of the unenlightened mind, that God fashioned all in the manner of an artificer, seeking by special means to produce special effects, but even the doctrine in vogue amongst men of science, that *creative fiats* were required for each new class, order, family, and species of organic beings, as they successively took their places upon the globe, or as the globe became gradually fitted for their reception.' According to the Bible, 'God said, Let us make man in our image, after our likeness. So God created man in His own image, in the image of God created He him.' But according to this theory, God created only microscopic monads and embryotic points, and from these, by a process of natural development, extending through cycles of ages, arose all the animated tribes. The Creator is bidden to retire to the utmost bound of creation. The system is one of order in which life grows out of dead matter; the higher out of the lower animals, and man out of the brutes."

In examining the successive fossil floras, we find at every epoch the same kind of subordination that we meet with at the present day, although certain tribes may have predominated at different periods. We do not find a set of cellular plants with no vascular species, nor do we find what are called the lowest types without individuals of the higher. Thus, at the time when the ferns were in the ascendency, dicotyledonous trees of a high type also existed, although apparently in less abundance; and so it is in the different stages. Sedgwick remarks:—

"The very earliest genera and orders were not organically inferior to the genera and orders of this day which we derive from corresponding grades in the scale of nature.

Nay, sometimes the primeval genera and orders are organically superior to their corresponding types in the living world. Again, the general organic plan of nature has been at all times not merely analogous, but identical. If genera, orders, and classes be now distinct and separate, they were equally distinct and separate in all periods of the old world. There is no development on the lines of organic ascent such as to produce confusion; but if the *theory of development* were true, there must be, on some parts of the organic scale, such a blending and penetration of types as would blot out and obliterate our lines of separation between genera, and orders, and classes. But we look in vain for any semblance of such obliteration; and, if we try to complete our present scale, by interpolating within it the organic types of the old world, we find no incongruity in our task. The oldest types fall into their place in the general scale, as naturally as the newest. We may, by this interpolation, improve and perfect our general scale; but we break not down the barriers between genera, and orders, and classes. They continue as strong and as abruptly marked as they were before."

This theory of natural development endeavours to exclude the supernatural as altogether needless. It removes God from His works, and puts them under the guidance of inevitable laws. It is the error of those who say, that "since the fathers fell asleep, all things continue as they were from the beginning of the creation" (2 Pet. iii. 4). The universe, according to them, is set a-going, and it must continue to progress—epoch after epoch displaying a greater development of what has gone before. The authors of the theory virtually deny God's sovereign power to interrupt what they call the order of nature, just as scoffers of old ignored the deluge (2 Pet. iii. 5-7). They suppose that germs were first formed, in what way they do not pretend to say, and that from these germs have sprung, in successive epochs, all the plants and animals of the globe. These living beings have, according to them, undergone successive transmutations, so that there have been no new creation—no sweeping away of one set of beings to make way for another. The original monad, once formed, all development goes on according to fixed laws as a matter of course. Such speculators will not entertain the idea, that by the fiat of the Almighty convulsions have occurred which have interrupted their continuous process of development, and have swept races of plants and animals away to be replaced by new creations. The deluge destroyed all the human race except eight persons who were miraculously preserved, and at the present day we see epidemics in operation which destroy vast multitudes of plants and animals. "During the present age, we have seen a new and terrible disease, quite as mysterious in its character and origin as any of those that have fallen on the potato or the vine, sweeping away more than a hundred millions of our own species. When these revelations of the age are read in the light of geological history, with its irrefragable evidence of the often-repeated extinction of entire creations, they seem to assume a peculiar significancy."

Three marked epochs have been described by fossil botanists characterised by the predominance of certain great divisions of plants:—1. The Reign of Acrogens; 2. The Reign of Gymnosperms, or naked-seeded Dicotyledons; 3. The Reign of Angiosperms, or of Monocotyledons and Dicotyledons, with seeds in seed vessels.

THE REIGN OF ACROGENS.—This includes what geologists call the Palæozoic strata, and embraces the great coal formation. In this epoch the families of ferns and their allies predominated, so far as we can judge by the fossil remains. Besides these, however, there were many specimens of Coniferous or cone-bearing Dicotyledons. Some of the plants connected with this period of the earth's history are seen in figs. 247 to 258. These represent

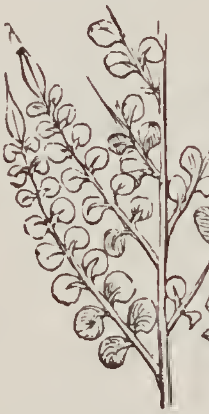


Fig. 247.

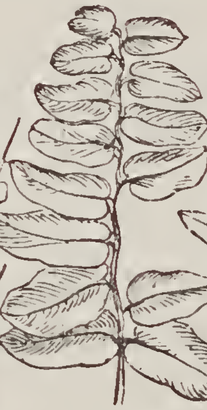
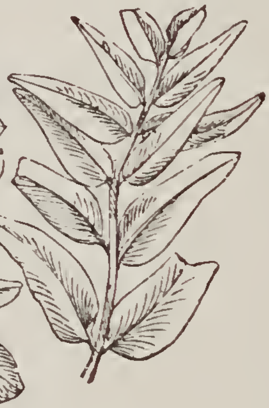


Fig. 248.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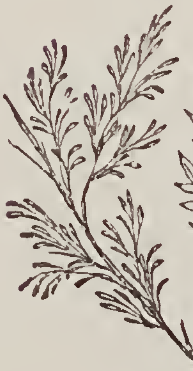
Fig. 250.

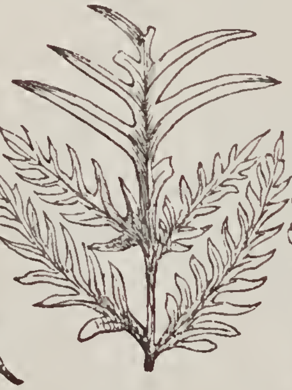
Fig. 251.

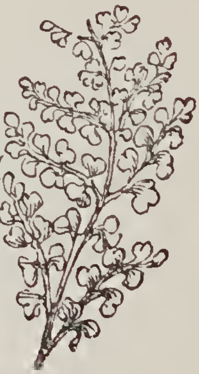
Fig. 252.

Fig. 247.—*Neuropteris Loshii*, a fossil-fern of the Coal Epoch.
Fig. 248.—*Neuropteris gigantea*, another fern of the same epoch.
Fig. 249.—*Neuropteris acuminata*, do. do.
Fig. 250.—*Sphenopteris affinis*, do. do.
Fig. 251.—*Pecopteris heterophyllus*, do. do.
Fig. 252.—*Sphenopteris dilatata*, do. do.

various species of extinct ferns and their allies. The ferns belong to the genera *Neuropteris*, *Sphenopteris*, and *Pecopteris* (figs. 247-253);—their allies being *Lepidodendron* (fig. 254), *Sigillaria* (figs. 255, 256), *Calamites* (fig. 257), resembling in appearance horsetails and *Stigmaria* (fig. 258), which is the root of *Sigillaria*. The peculiar markings on the stems of the plants of the Carboniferous epoch led Hugh Miller to speak of it as the *sculpturesque*

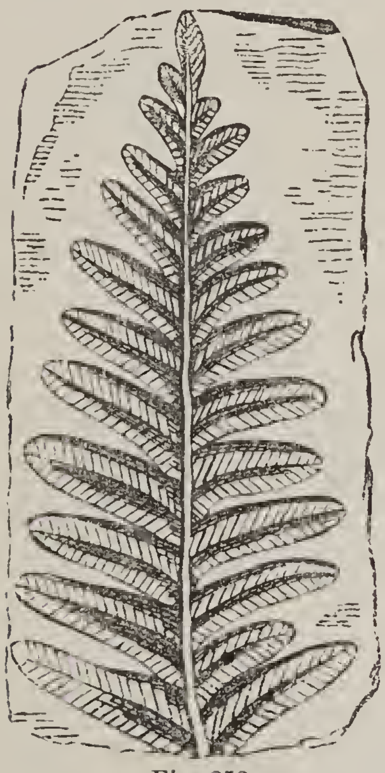

Fig. 253.

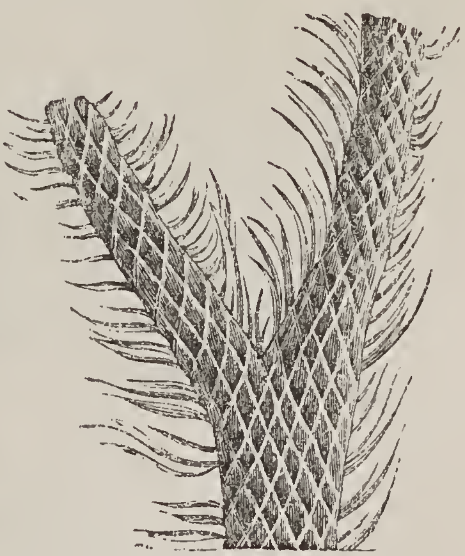

Fig. 254.

Fig. 253.—*Pecopteris aquilina*, a fossil-fern of the Coal Epoch.
Fig. 254.—*Lepidodendron elegans*, a fossil of the Coal Epoch, allied to *Lycopodiums* of the present day.

epoch. He says, that "in walking among the ruins of this ancient flora, the palæontologist almost feels as if he had got among the broken fragments of Italian palaces, erected long ages ago, when the architecture of Rome was most ornate, and every moulding was roughened with ornament; and, in attempting to call up in fancy the old carboniferous forests, he has to dwell on this peculiar feature as one of the most prominent, and to see in the multitude of trunks darkened above by clouds of foliage that rise upon him in the prospect, the slim columns

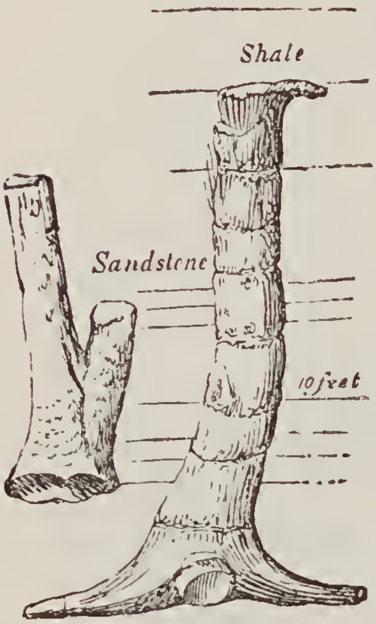

Fig. 255.

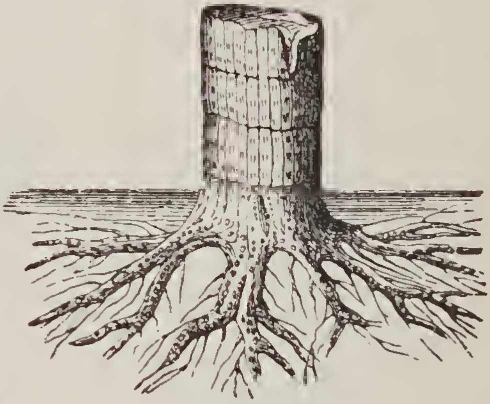

Fig. 256.

Fig. 255.—*Sigillaria pachyderma*, a fossil of the Coal Epoch, allied to ferns. It is represented in an erect position covered by successive deposits of sandstone and shale. One of the stems is bifurcated.

Fig. 256.—Lower part of stem of *Sigillaria reniformis*, with its roots consisting of *Stigmaria ficoides*.

of an elder Alhambra, roughened with arabesque tracery and exquisite filigree work." *

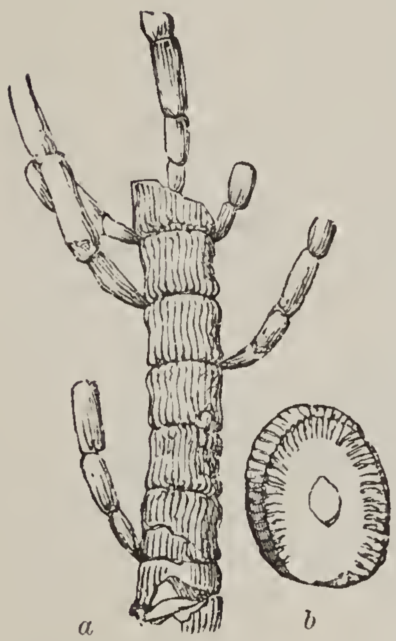

Fig. 257.

Coal is well ascertained to be of vegetable origin, and was probably formed by the compression of immense trunks of Acrogens and of other trees which were drifted into large troughs or basins by the action of water. The attempts, however, of philosophers and lawyers to define what coal is, have failed. Coal has become, according to Forbes, a geological chameleon. Opinions on this subject must necessarily vary according to the point of view, whether chemical, geological, mineralogical, or microscopical, at which we regard it. By making an *à priori* rule as to what coal should be, any man may arrive at a strict specific character, and more than one view of the matter may be right. Coal varies much in its characters, as seen in anthracite, household

Fig 257.—*Calamites Mougeotii*, a jointed stem, resembling that of an Equisetum in some respects, but differing in having an apparent bark;—*a* branching-stem; *b* partition of one of the joints.

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* Miller's Testimony of the Rocks, p. 38.

coal, cannel coal, etc.; and under these heads, there are endless varieties. It is not easy to tell where shale ends and coal begins. It is rare to find any distinct vegetable structure in coal, in consequence of the change produced by the compressing force to which it has been subjected. In some kinds of coal, however, cellular and other structures have been detected, on examining sections of them under the microscope. The mass of vegetation concerned in the formation of our coal-beds must have been enormous. The prospective beneficence of the Creator is seen in covering the earth at that epoch of its history with a luxuriant vegetation, and in storing it up in subterranean strata as enduring beds of coal, which, by subsequent volcanic actions, have been rendered accessible to man, and have become to him, in these latter days, the source of heat and light. Thus, while the surface of the

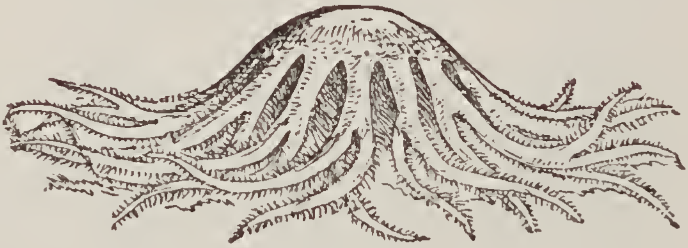

Fig. 258.

Fig. 258.—*Stigmaria ficoides*, a plant very abundant in the Coal Measures, constituting the roots of Sigillaria.

earth is given to man whence to obtain his food, the substrata are made to furnish that material which is required to dress it, and to raise man in the scale of civilisation. Along with coal we frequently meet with iron, that most important metal; and associated with it is limestone, which is required for a flux to separate the metal from its ore. Thus by the union of coal, iron, and limestone, man is enabled to prepare the metallic treasures of the earth for his use.

In speaking of the Bohemian coal mines, Buckland remarks, "The most elaborate imitations of living foliage upon the painted ceilings of Italian palaces bear no comparison with the beauteous profusion of extinct vegetable forms with which the galleries of these instructive coal mines are overhung. The roof is covered as with a canopy of gorgeous tapestry, enriched with festoons of most graceful foliage flung in wild and irregular profusion over every portion of its surface. The effect is heightened by the contrast of the coal-black colour of these vegetables with the light groundwork of the rock to which they are attached. The spectator feels himself transported, as if by enchantment, into the forests of another world; he beholds trees of forms and characters now unknown upon the surface of the earth, presented to his senses, almost in the beauty and vigour of their primeval life; their scaly stems (fig. 254, p. 363) and bending branches, with their delicate apparatus of foliage, are all spread forth before him, little impaired by the lapse of countless ages, and bearing faithful records of extinct systems of vegetation, which began and terminated in times of which these relics are the infallible historians. Such are the grand herbaria wherein these most ancient remains of the vegetable kingdom are preserved, in a state of integrity little short of their living perfection, under conditions of our planet which exist no more."

The vegetation of the Coal Epoch seems to resemble most that of islands in the midst of vast oceans, and the prevalence of ferns indicates a climate similar to that of New Zealand in the present day. In speaking of the island vegetation of the Coal Epoch, Professor Ansted remarks:—"The whole of the interior of the islands may have been clothed with thick forests, the dark verdure of which would only be interrupted by the bright green of the swamps in the hollows, or the brown tint of the ferns covering some districts near the coasts. The forests may have been formed by a mixture of several different trees. We would see then, for instance, the lofty and widely-spreading Lepidodendron (fig. 254, p. 363), its delicate, feathery, and mosslike fronds clothing, in rich luxuriance, branches and stems which are built up, like the trunk of the tree-fern, by successive leaf-stalks that have one after another dropped away, giving by their decay additional height to the stem, which might at length be mistaken for that of a gigantic pine. There also should we find the Sigillaria (figs. 255, 256, p. 364), its tapering and elegant form sustained on a large and firm basis, enormous matted roots, almost as large as the trunk itself, being given off in every direction, and shooting out their fibres far into the sand and clay in search of moisture. The stem of this tree would appear like a fluted column, rising simply and gracefully without branches to a great height, and then spreading out a magnificent head of leaves like a noble palm-tree. Other trees, more or less resembling palms, and others, like existing firs, also abounded, giving a richness and variety to the scene; while one gigantic species, strikingly resembling the Norfolk Island pine (fig. 64, p. 80), might be seen towering a hundred feet or more above the rest of the forest, and exhibiting tier after tier of branches richly clothed with its peculiar pointed spear-like leaves, the branches gradually diminishing in size as they approach the apex of a lofty pyramid of vegetation. Tree-ferns (fig. 242, p. 337) also in abundance might there be recognised, occupying a prominent place in the physiognomy of vegetation, and dotted at intervals over the distant plains and valleys; the intermediate spaces being clothed with low vegetation of more humble plants of the same kind. These, we may imagine, exhibiting their rich crests of numerous fronds, each many feet in length, and produced in such quantity as to rival even the palm-trees in beauty. Besides all these other lofty trees of that day, whose stems and branches are now called Calamites (fig. 257, p. 365), existed chiefly in the midst of swamps, and bore their singular branches and leaves aloft with strange and monotonous uniformity. All these trees, and many others that might be associated with them, were perhaps girt round with innumerable creepers and parasitic plants, climbing to the topmost branches of the most lofty amongst them, and relieving, in some measure, the dark and gloomy character of the great masses of vegetation."

"Few persons," says Buckland, "are aware of the remote and wonderful events in the economy of our planet, and of the complicated application of human industry and science, which are involved in the production of the coal that supplies the metropolis of England. The most early stage to which we can carry back its origin was among the swamps and forests of the primeval earth, where it flourished in the form of gigantic Calamites, and stately Lepidodendra, and Sigillariæ. From their native bed these plants were torn away by the storms and inundations of a hot and humid climate, and transported into some adjacent lake, or estuary, or sea. Here they floated on the waters, until they sank saturated to the bottom, and, being buried in the detritus of adjacent lands, became transferred to a new estate among the members of the mineral kingdom. A long interment followed, during which a course of chemical changes and new combinations of their vegetable elements have converted them into the mineral condition of coal. By the elevating force of subterranean fires, these beds of coal have been uplifted from beneath the waters, to a new position in the hills and mountains, where they are accessible to the industry of man. From this fourth stage in its adventures, our coal has again been removed by the labours of the miner, assisted by the arts and sciences that have co-operated to produce the steam-engine and the safety-lamp. Returned once more to the light of day, and a second time committed to the waters, it has, by the aid of navigation, been conveyed to the scene of its next and most considerable change by fire; a change during which it becomes subservient to the most important wants and conveniences of man. In this seventh stage of its long eventful history, it seems to the vulgar eye to undergo annihilation; its elements are indeed released from the mineral combinations they have maintained for ages, but their apparent destruction is only the commencement of new successions of change and of activity. Set free from their long imprisonment, they return to their native atmosphere, from which they were absorbed to take part in the primeval vegetation of the earth. To-morrow, they may contribute to the substance of timber, in the trees of our existing forests; and having for a while resumed their place in the living vegetable kingdom, may ere long be applied a second time to the use and benefit of man. And when decay or fire shall once more consign them to the earth, or to the atmosphere, the same elements will enter on some further department of their perpetual ministration in the economy of the material world."

THE REIGN OF GYMNOSPERMS.—During the epoch between that last noticed and the chalk period, the vegetation seems to have undergone a marked change. This period corresponds to the lower and middle secondary strata of geologists. Acrogens are less numerous, and dicotyledonous plants, having seeds not contained in ovaries, and hence called naked-seeded, predominate. These plants are represented by cone-bearing trees, such as pines (fig. 237, p. 332), where the cones containing the seeds are not considered as ovaries, but as composed of scales or leaves bearing seeds at their base (fig. 168, p. 226). They are also represented by the Cycas family, or plants yielding a kind

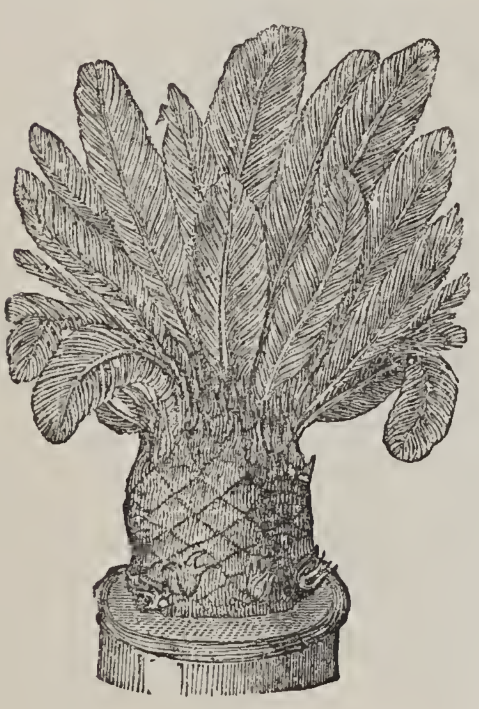

Fig. 259.

Fig. 259.—*Cycas revoluta*, one of the naked-seeded dicotyledons, resembling those which characterised the reign of Gymnosperms.

of sago, which are shown in figs. 259, 260. These plants bear naked seeds on the edges of transformed leaves. They have no true pistil, and the pollen is applied directly to the seed. Some of the stems of the fossil Cycads occur in an erect position in what is denominated the Portland Dirt-bed, consisting of earthy brown matter of a peculiar character. One of the fossil Cycads is represented in fig. 261;

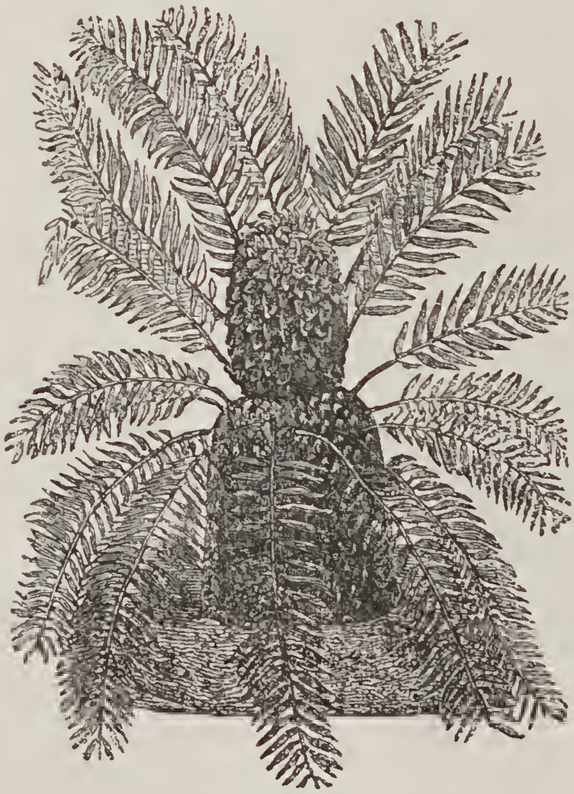

Fig. 260.

Fig. 260.—*Zamia* or *Encephalartos pungens*, another plant of the Cycas tribe, having naked seeds, and hence called gymnospermous.

and the ovate cone of another is seen in fig. 262.

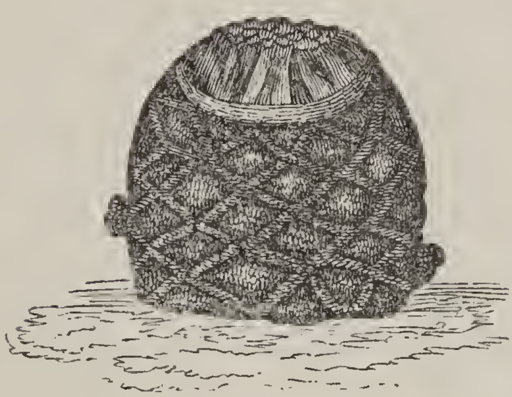

Fig. 261.

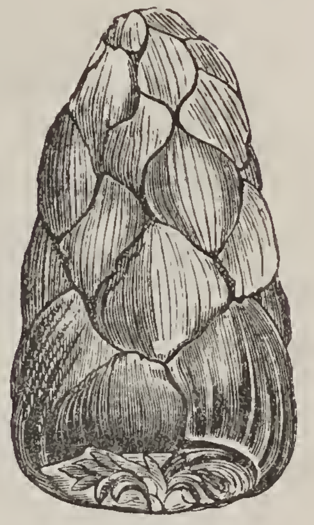

Fig. 262.

THE REIGN OF ANGIOSPERMS.—This includes the epoch which commences with the chalk and ends at the conclusion of the tertiary period, or that immediately preceding the present flora of the globe. There is a predominance in this epoch of plants resembling more nearly those of the present day. These belong chiefly to the divisions of monocotyledons and

Fig. 261.—*Cycadoidea megalophylla* (*Mantellia nidiformis* of Brongniart), a subglobose depressed trunk, with a concave apex, and with the remains of the petioles disposed in a spiral manner, the markings being transversely elliptical. It is found in the Oolite of the Island of Portland, in a silicified state.

Fig. 262.—*Zamiostrobus ovatus* (*Zamia ovata* of Lindley and Hutton), an ovate cone with a truncated base and obtuse apex. The genus seems to be intermediate between Encephalartos and Zamia. It is found in the green-sand at Faversham (Lindley and Hutton).

dicotyledons, having seed-vessels, and hence called Angiosperms. In fig. 263 there is represented a leaf of one of the tertiary fossil plants. It appears to belong to the genus Acer, or maple of the present day.

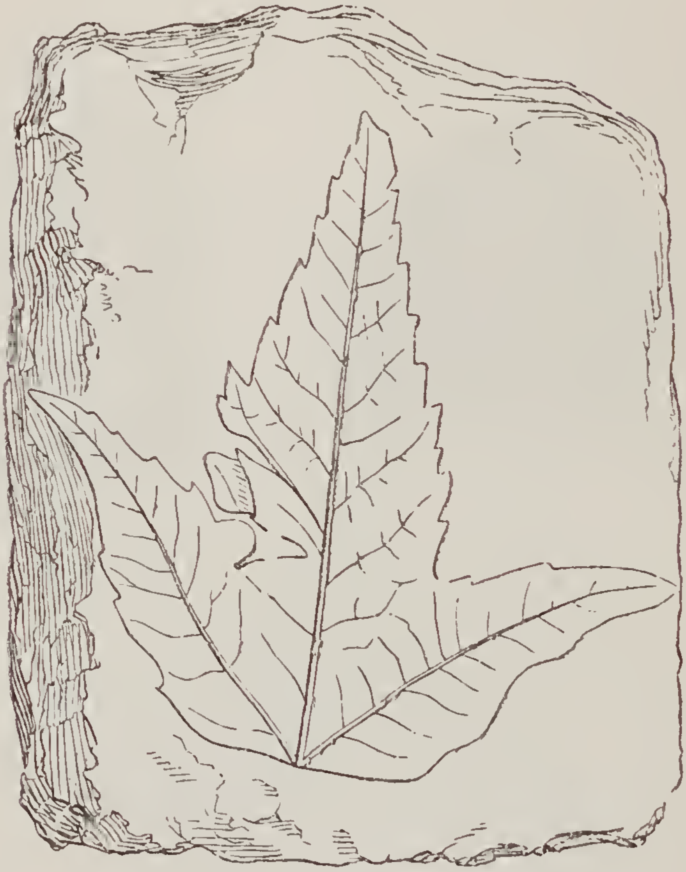

Fig. 263.

"The pre-Adamic history of our globe," Miller remarks, "is recorded in the rocks; and

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Fig. 263.—*Acer trilobatum*, a three-lobed palmate leaf, like that of the Maple, with the lobes unequal, inciso-dentate, the lateral ones spreading, found at Œningen.

organisms are the significant and impressive characters of it. The very gaps which occur in the long chronicle serve all the more strongly to divide it into periods, each furnished with its own independent group of being, specifically unlike that which went before, or that which followed after, and suited to remind us all the more emphatically in consequence, that to every species that ever lived in the old geologic ages there came a 'last day.' We have been long accustomed to recognise the inexorable reign of death in its relation to individuals, and to regard it as one of the most assured and certain of all things, that as all who have lived upon our earth during the ages of the past have died, so it is 'appointed for all' who now live upon it 'once to die.' The same experience which leads us to anticipate that the sun will rise and set to-morrow, just because the sun has risen and set during all the many days of the past, leads us also to anticipate that all the individual creatures which now inhabit the earth will die, just because all the individual creatures which inhabited the earth in the bygone ages *have* died. And we now find geology extending this uniform experience of death from individuals to species, and compelling us to believe, on the strength of the argument to which we so unhesitatingly yield in the other cases, that as all the *species* of the past have died, so it is destined for all the species of the present also to die. The theologian had to contend in the last age with a class of sceptics who,—their scepticism assuming, as is not very uncommon, the form of credulous belief,—used to argue that there had been an infinite series of men upon earth; and, of course, if the race had no beginning, could it be held in consistency that it was to have an end? We now absolutely know, as geologists, not only that a beginning there was, but that that beginning was a comparatively recent event; and further, founding on the unvarying experience of the past, we also know that the race, in at least its existing character and condition, is to have an end."* "Fixed upon the pedestal of his native earth," Sir David Brewster remarks, "and with no other instrument but the eye and the hand, the genius of man has penetrated the dark and distant recesses of time and space. The finite has comprehended the infinite. The being of a day has pierced backwards into primeval time, deciphering its subterranean monuments, and inditing its chronicle of countless ages. The

* Hugh Miller on the Fossiliferous Deposits of Scotland.

stones and boulders over which we stumble in our path, and the sand and mud upon which we daily tread, are the witnesses of those gigantic dislocations of the pavement of our globe, by which our seas and continents have changed places—by which our mountain ranges have emerged from the bed of the ocean, and mighty cycles of animal and vegetable life have been embalmed and entombed."

Thus all the phenomena connected with fossil plants show that great changes have taken place in our planet during its preparation for the abode of man, the noblest of God's works on earth ; and they lead us to think of that final change when the earth shall be renewed and made a habitation of righteousness and peace. "But the day of the Lord will come as a thief in the night; in the which the heavens shall pass away with a great noise, and the elements shall melt with fervent heat, the earth also and the works that are therein shall be burnt up. Seeing then that all these things shall be dissolved, what manner of persons ought ye to be in all holy conversation and godliness, looking for and hasting unto the coming of the day of God, wherein the heavens being on fire shall be dissolved, and the elements shall melt with fervent heat ? Nevertheless we, according to His promise, look for new heavens and a new earth, wherein dwelleth righteousness. Wherefore, beloved, seeing that ye look for such things, be diligent that ye may be found of Him in peace, without spot, and blameless" (2 Pet. iii. 10-14).

"In prosecuting our geological researches in a right spirit, we need not fear that we shall ever arrive at a point where the knowledge of nature will be found to be at variance with the truth of Scripture. The volume of Nature and the volume of Inspiration are the products of the same Omniscient Mind. God is the Author of both; and the more thoroughly each is studied, the more shall we be constrained to admit the unnumbered harmonies which subsist betwixt the two, and the beautiful light of illustration which they reciprocally shed on one another. Founding on this simple consideration of the common authorship of the two volumes, we may discard every jealousy of true science, and say with confidence that Christianity has everything to hope and nothing to fear from the advancement of philosophy. There is a knowledge of nature which is essentially atheistic, but this arises not from superabundance, but from defect of knowledge; not from its going beyond, but from its stopping short of its legitimate bounds." All the discoveries of geology tend only to confirm the statements of Scripture, as has been ably shown by Dr King in his work on the connection between Geology and Religion.

On the subject of Bible-teaching in reference to the laws of nature, the following remarks of Gaussen deserve to be studied:—"Open the Bible, examine the fifty sacred authors therein, from Moses—who wrote in the wilderness 400 years before the siege of Troy—to the fisherman son of Zebedee—who wrote 1500 years later in Ephesus and Patmos, under the reign of Domitian—and you will find none of those mistakes which the science of every country detects in the works of preceding generations. Carefully go through the Bible from Genesis to Revelation in search of such faults, and, as you carry on the investigation, remember that it is a book which treats of everything, which describes nature, which recounts its wonders, which records its creation, which tells us of the formation of the heavens, of the light, of the waters, of the air, of the mountains, of animals, and of plants;—that it is a book which acquaints us with the first revolutions of the world, and which foretells also its last;—that it is a book which describes them with circumstantial details, invests them with sublime poetry, and chants them in fervent melodies;—that it is a book replete with Eastern imagery, full of majesty, variety, and boldness;—that it is a book which treats of the earth and things visible, and at the same time of the celestial world and things invisible;—that it is a book in which nearly fifty writers, of every degree of cultivation, of every order, of every condition, and separated from one another by 1500 years, have been engaged;—that it is a book written variously in the centre of Asia, in the sands of Arabia, in the deserts of Judea, in the porches of the Jewish Temple, and in the rustic schools of the prophets of Bethel and Jericho, in the magnificent palaces of Babylon, and on the idolatrous banks of the Chebar, and afterwards in the centre of western civilisation, in the midst of the Jews and their ignorant councils, among polytheism and its idols, and as it were in the bosom of pantheism and its foolish philosophy;—that it is a book whose first writer was, during forty years, brought up among the magicians of Egypt, who regarded the sun, planets, and elements as endowed with intelligence, reacting upon and governing our world by their continual evaporation;—and that it is a book whose first pages preceded, by more

than 900 years, the most ancient philosophers of Greece and Asia, Thales, Pythagoras, Zaleucus, Xenophon, and Confucius;—that it is a book which carries its records into the scenes of the invisible world, the hierarchy of angels, the latest periods of futurity, and the glorious consummation of all things. Well, search in its 50 authors, its 66 books, its 1189 chapters, and its 31,173 verses,—search for a single one of the thousand errors with which every ancient and modern author abounds when they speak of the heavens or of the earth, of their revolutions or their elements, and you will fail to find it. . . . .
The Bible never does violence to facts, nor to the principles of sound natural philosophy. Never in one single instance will you find it in opposition to the just ideas which science has given us regarding the form of our globe, its magnitude, and its geology. . . . .
There is, therefore, no physical error whatever in the Scriptures; and this transcendent fact, which becomes more admirable in proportion as it is made the subject of closer investigation, is a striking proof of the inspiration which dictated them, even to their least expressions."

Effects of Plants on the Sand of the Shore, and on the Mud of Rivers.—Even at the present geological epoch, plants are concerned in the changes which are taking place in the soil of our globe, and in fixing the loose sand of our shores. The roots and underground stems of plants growing in these situations extend themselves widely in all directions in search of food, and thus become interwoven together, so as to sustain the soil in a sort of basket-work, and consolidate the sands thrown up by the waves of the ocean. This is well seen in the case of the common bent or marram of our shores, and in some of the species of carex growing in the sand (fig. 264). In Madras the ground-rattan (*Spinifex squarrosus*) acts as a sand-binding plant. The great sea-dyke which prevents the inundation of Holland is said to owe its stability in a great measure to the plants which grow upon it. Plants also increase the quantity of dry-land by growing in the mud deposited by rivers at their mouth. The quantity of mud carried down by rivers at the present day is immense. Ansted states that the Rhine at Bonn has been calculated to carry down 400 tons of solid matter per hour; and in the course of one year 7000 to 8000 millions of tons. The whole of the Delta of the Ganges, comprising 20,000 square miles, has been formed by that river and its tributaries. The quantity of mud car-

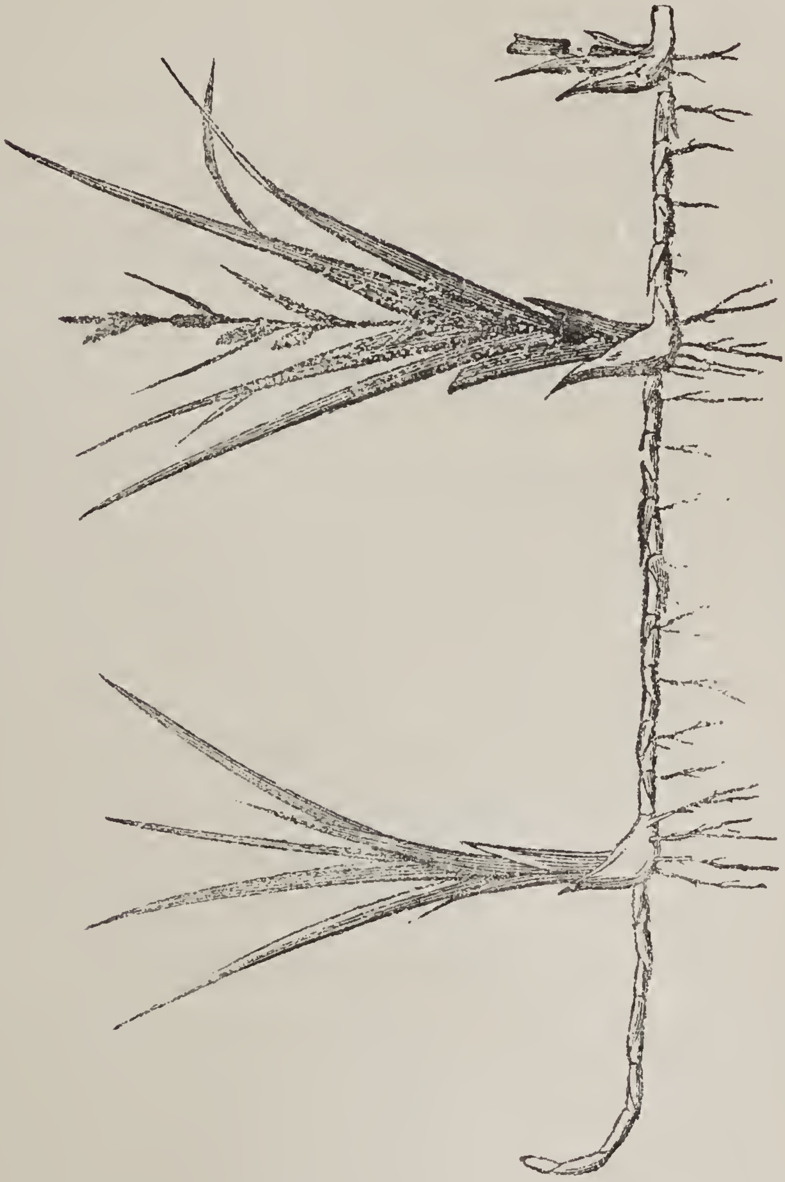

Fig. 264.

Fig. 264.—Sand Carex (*Carex arenaria*), which with its underground stems and roots tends to consolidate the sands on the sea-shore.

ried down in the rainy season is so great, that it may be detected 60 miles from the coast. In the flood season, Major Rennel calculates that 450 millions of tons of mud are brought down by the Ganges daily. The Delta of the Irrawaddy, according to Login, is about 140 miles long, and has an area of land of 7500 square miles, which has been made by the mud of the river. The average discharge of the river is 350,000 cubic feet per second, containing silt by weight equal $\frac{1}{3000}$ part. Thus about two thousand millions cubic feet of silt annually pass. The quantity of water discharged annually by the Mississippi is said to be 14,883,360,636,880 cubic feet, and the sediment discharged by it annually has been estimated at 28,188,083,892 cubic feet. It is said that the muddy nature of the Amazon may be seen in the ocean at the distance of 300 miles from its mouth. This mud, when deposited, is speedily taken possession of by plants, and thus its stability is secured. Out of the deposits of the Rhine the greater part of Holland has thus been formed, and out of those of the Po a large portion of the Venetian territory has arisen. The papyrus of the ancients, the bulrush of the Scriptures (fig. 21, p. 29), has contributed in no small degree to form the

Delta of the Nile; and the mangrove trees (fig. 47, p. 65) of the present day are thus contributing to the formation of new land in tropical countries. The seeds of the mangrove germinate before being detached from the branches, and when they drop into the loose mud in which the plant grows, they immediately become trees with singular stems, which divide near the base, and allow the water of the tide and the rivers to flow freely between them. By the double agency of roots and germinating seeds there is thus a very rapid acquisition of new land, which, although swampy and unwholesome at first, ultimately may be made fit for the habitation of man.

> "And such the mangrove, which, at full-moon flood,
> Appeared itself a wood upon the waters,
> But when the tide left bare its upright roots,
> A wood on piles suspended in the air."
>
> —MONTGOMERY.

We find man himself pursuing the same system, and, whether he knows or not that he is imitating nature, sowing vegetation to secure and consolidate the mud which his piers and dams have detained, that he may gain a new territory from the waters, or arrest the progress of the sands which might be blown by the wind so as to injure the land. Thus does the marsh at length become a plain fitted for pasturage and agriculture, and the sands are consolidated and prevented from shifting.

II.—BEARINGS OF BOTANY ON ZOOLOGY.

The lowest tribes of plants become in an especial manner an object of study to the zoological inquirer, in consequence of the great similarity which exists between them and the lowest tribes of animals. For, while there are wide and marked differences between the higher plants and animals, the lowest members of these two kingdoms of nature approach so nearly, that it is difficult to tell where the one begins and the other ends. Thus sponges, which are considered as belonging to the lowest class of animals, were at one time looked upon as vegetables; and the common coralline (*Corallina officinalis*) has been lately transferred from the domain of the zoologist to that of the botanist. Some bodies which Ehrenberg represents as infusory animals, are now considered as being of vegetable origin.

The most careless observer must have noticed on the sea-shore many interesting productions, to all appearance of a vegetable nature, resembling plants in their form and habits;—some of them being arborescent in their mode of growth, and fixed by roots to rocks, stones, and other substances, in the same manner as sea-weeds. The opinions of naturalists were long divided concerning these bodies, and we are indebted to the work of Mr John Ellis on Corallines for the proof of their animal nature.

> "Involved in sea-wrack here we find a race
> Which science, doubting, knew not where to place;
> On shell or stone is dropp'd the embryo seed,
> And quickly vegetates a vital breed."

There are still, however, many productions which occupy an intermediate space between the animal and vegetable kingdom, and for the time being the zoologist and botanist must consent to joint occupancy. The existence of movements is by no means sufficient to form a line of demarcation, for many true sea-weeds exhibit distinct motions in their spores; and it has been recently stated that analysis can do little to help us in many cases; for cellulose, which has been long considered as characteristic of plants, has recently been detected in the structure of the tunics of the animals called Ascidians. Thus, whether we regard structure, functions, or chemical composition, we encounter great difficulties in distinguishing between the lowest members of the animal and vegetable kingdoms, and much still requires to be done ere we can come to any satisfactory conclusion.

Some of the minute plants called Diatoms, which are on the confines of the animal kingdom, occur in enormous quantity. Thus myriads of them are found in the mud at the mouths of rivers, in the bottom of the ocean, and in various deposits of peat and sand on the surface of the globe. In some peat sent from Cantyre by the Duke of Argyll, Dr Gregory found at least fifty species of diatoms in immense quantity. Such is also the case with peat in Ireland, examined by Professor Smith, and peat at Premnay, Aberdeenshire, examined by Professor Dickie. The same species are widely diffused, and they seem to be capable of enduring great extremes of heat and cold. They were discovered in millions in pancake ice and in the deep soundings in the highest latitudes reached by the antarctic expedition, and they also occur in vast numbers on the branches of trees in the virgin forests of South America.

It would appear, from the researches of Ehrenberg, that in the atmosphere we breathe there are numerous species of diatoms which are carried by the winds and deposited in various spots. The immense quantity of matter so transported is proved by the various instances of black and coloured rains, consisting of soot, pollen, or other substances, which have been conveyed often to a great distance; and there is no doubt that myriads of minute species of fungi and other cryptogamous plants are thus diffused. The sirocco and trade-winds convey organisms for hundreds of miles. These have been found by Ehrenberg to be myriads of infusorial animals and diatomaceous plants. Clouds of dust sometimes colouring the atmosphere orange or ochre, have been observed. These clouds of dust occur within the course of the trade-winds, and have been seen coming in various directions from the coast of Africa, as at Malta, Genoa, Lyons, and Silesia. The dust consists of various land and fresh-water diatoms, the flinty spicula of sponges and other zoophytes, pollen grains, fragments of phanerogamous plants, such as hairs, cuticle, and various internal parts of structure, and some spores of fungi. The matters contained in these currents may lead to interesting observations as to the direction of winds, and various meteoric phenomena. Coloured snow in the Tyrol has been shown to be in some instances due to the same cause as coloured rain. What have been called showers of blood are, in reality, nothing but the sudden growth of *Palmella cruenta,* one of the lower plants, at the base of damp walls. Black rain fell in Ireland in April 1849 over a district of 700 square miles, and was due to portions of decayed plants mixed with diatoms.

III.—BEARINGS OF BOTANY ON MEDICINE IN ITS VARIOUS DEPARTMENTS.

To students of medicine, botany is valuable in many points of view. In some respects it may be looked upon rather as an ally than as a province of medicine—as a connecting link between professional and purely scientific studies. It is too often supposed that botany is of little use to the student of medicine, and that all he acquires by his attendance at botanical lectures is a knowledge of the names, classes, and orders of medicinal plants. On this subject, Professor Edward Forbes remarks, "That the true object of the connection of natural history studies with more professional pursuits is frequently lost sight of. The object of these sciences is not merely to teach the student a certain number of facts, the recollection of which may be useful to him in after-life; but to train his mind, by means of the peculiar forms of research which characterise those sciences, to that tone and vigour which must be of the utmost consequence in giving him power for future and professional avocations of a different character, especially such as are to form the after-occupation of the student of medicine. A judicious practitioner requires accurate observation and acute diagnosis, and these qualities are constantly brought into vigorous exercise in the prosecution of botanical investigations. Not unfrequently do we hear the short-sighted and narrow-minded ask, what is the use of zoology, or botany, or geology to the physician or surgeon? what have they to do with beasts, or plants, or stones? Is not their work among men healing the sick? Of what use, save as remedies, can the creeping things, or the grass that grows upon the earth, or the minerals in the rock be to the practitioners of medicine? Vain and stupid questions all—yet they are sometimes put by persons who profess to promote the spread of education. They want something, but the best of them mistake the end for the means. The best want knowledge, but have not learned that the mind must be trained ere it is prepared to gather and digest knowledge. They want science, but science turns mouldy and unwholesome in an unprepared mind. They forget, or do not know, that education consists chiefly in training, not in informing.

"We must counteract the natural tendency of purely professional studies—the tendency to limit the range of mental vision. We can do this most beneficially through the collateral sciences, which are sufficiently allied to the professional ones to prevent an undue dissipation of the student's thoughts, and at the same time are sufficiently different to give them a wider sphere of action. It is in this point of view that we should regard the natural history sciences as branches of medical education. For my own part," continues Forbes, "after much intercourse with medical men who had studied at many seats of professional education, some collegiate, some exclusively professional, I have no hesitation in saying that as a rule, the former had the intellectual advantage. There are noble and notable exceptions, old and young, but the rule is true in the main. The man who has studied in a seat of learning, a college, or university, has a wider range of sympathies, a more philosophical tone of mind, and a higher estimate of the objects of intellectual ambition than his fellow practitioner who, from his youth upwards, has concentrated his thoughts upon the contractedly professional subjects of an hospital school. I will not believe that the practitioner of medicine, any more than the clergyman or the lawyer, or the soldier or the merchant, is wiser or better able to treat the offices of his calling, because his mind takes no note of subjects beyond the range of his professional pursuits. It is a great pleasure both to patient and neighbour to find in our doctor an enlightened friend, one who, whilst he does his duty ably and kindly, has a sympathy and an acquaintance with science, literature, or art."

The object of a university is not merely to examine and grant degrees, but to train the minds of youth for the proper acquisition of knowledge, and to direct their energies in such a way as to ensure that mental culture which will fit them for all the duties of life. A medical man ought not to rest satisfied with a knowledge of the purely practical parts of his profession. His mind ought to be well stored with literary and scientific information; and were more attention paid to these studies, the profession generally would occupy a higher position than it does at present. The Commissioners for visiting the Universities of Scotland make the following statement in their report:—"It is a matter about which all are agreed, that it is desirable that medical practitioners should be men of enlightened minds, accustomed to exert their intellectual powers, and familiar with habits of accurate observation and cautious reflection. It is also desirable that they should have that degree of literary attainment which will prevent them, when mingling as they must do with mankind in the exercise of their profession, from being looked upon with contempt, or from committing errors in conversation and in writing for which others would be despised: because, even upon the supposition that, notwithstanding this, they have high professional acquisitions, the law of association will operate, and the conclusion will be drawn, that much confidence cannot be placed in them. This tendency not to confide in them, is one of the most formidable difficulties with which a physician has to struggle, much, unquestionably, of the success of ordinary practice depending upon the feelings of trust or security with which he is regarded. It is also of importance that a class of men, so widely diffused, and mingling so much with society, as the members of the medical profession, should be so instructed as to be able to give a tone to conversation, and to promote among those with whom they associate the love and the pursuit of literary and scientific accomplishments."

Placed as a medical man frequently is in circumstances where he cannot have all the usual remedies at hand, he may be enabled, by his acquaintance with the structure and alliances of plants, to substitute with certainty one species for another. He may also be able to give an opinion as to their poisonous or esculent qualities, and may thus materially aid in the preservation of the life of a crew on a foreign and unknown shore. All who study the functions of the human body, will find it to their advantage to become in the first instance acquainted with the vital phenomena presented by plants. Many of the processes carried on in plants are more easily studied; and from an examination of them, important aid has been given to the science of human physiology. All classes of living beings must be embraced in the inquiries of the student who would become a scientific physiologist.

To the organic chemist who examines the mode in which the functions of living bodies are carried on, plants present objects of high interest. They may be looked upon as the great laboratories of nature, by means of which the materials of the atmosphere and the soil are rendered fit for the nourishment of man and animals. They constitute the herbage upon which animals feed, and they elaborate the nutritious matter from which our bread is prepared. Moreover, they act an important part in those atmospheric changes which are essential for the process of respiration. The life of plants is intimately connected with that of animals. The presence of a rich and luxuriant vegetation may be conceived without the concurrence of animal life, but the existence of animals is undoubtedly dependent on the life and development of plants.

Although chemistry has enabled us to explain many of the changes which take place in the soil and atmosphere, by the agency of plants, still much is wanting ere we can understand the processes of assimilation which go on in the vegetable tissues. A blade of grass, says Dr Brown (that yet mysterious community of parts, so consummate in living oneness), imbibes the moisture of the earth, inhales the fixed air and the ammonia of the atmosphere, and weaves its own expanding form, with all its delicate organs and their susceptibilities, out of their dismembered particles. By a similar but more wondrous alchemy is the herbage of the fields transformed into the quivering fibre of still higher and higher forms of animated existence. And of all these stupendous operations we know absolutely nothing. Water, carbonic acid, and ammonia are traced into the vessels of plants, but no farther. An organism dies, and once more falls down into the ammonia, carbonic acid, and water, from which it sprang. The chemist does all he can to investigate these changes, but he has not been able to explain the process of organisation.

IV.—BEARINGS OF BOTANY ON AGRICULTURE, HORTICULTURE AND THE ART OF DESIGN.

To the student of agriculture, botany presents an important field of inquiry. The knowledge of the mode in which plants germinate and derive nourishment, aids him in the various operations of draining, ploughing, sowing, and manuring. In speaking of the sprouting of the seed, we have already noticed the requisites for this process, and have pointed out the necessity of attention to the circumstances in which the seed is placed in the soil. Each plant during its growth takes up certain matters from the soil, particularly inorganic substances, as silica and salts of lime, potass, and soda; and some plants take up more of one kind than of another. It is on this principle that the rotation of crops rests, plants being made to succeed each other which require different substances for their nutrition. Now that the chemist and vegetable-physiologist have been called to the aid of agriculture, the farmer is enabled, by an analysis of his crop, of his land, and of his manure, as well as by attention to proper draining and sowing, to carry on his operations in an enlightened manner, and not under the guidance of a blind empiricism.

The art of horticulture, too, owes much to the labours of the vegetable-physiologist, as may be seen by the examination of Lindley's able work on the "Theory of Horticulture." The effect of soil and of proper exposure to light and air in the formation of wood and various vegetable products, in giving colour to flowers, and flavour to fruits, are now well ascertained. No one can be a successful gardener who does not act according to the correct principles of botanical science.

Professor Forbes says, "The relations of natural history with the arts are of two kinds —either illustrative or suggestive. To the first belongs the inquiry into the nature and sources of the numerous products derived from the animal and vegetable kingdoms, and applied, or capable of being applied, as direct materials for art and manufactures. A more perfect acquaintance with old, and a discovery or indication of new, materials, adapted to the exercise of human skill and workmanship, may thus be attained. But the naturalist may render higher, and at the same time as practical, services to the craftsman, by furnishing, out of the endless store of beautiful objects that are rendered familiar to him by his scientific pursuits, sources of new and exquisite design, fancies originating in the teeming brain of nature,—God-born thoughts, that become manifest in living shapes—all consistent—never jarring—in every part admirably adapted to each destined purpose. The laws of these adaptations and harmonies, the proportion by which the beauty of living things is maintained, the ideas by which similar forms have been grouped in nature, and though like exceedingly, yet wondrously dissimilar—these are among the earnest studies of every philosophical naturalist. Surely out of such studies lessons applicable to art may be derived. What is ornamental art but the isolation and embodiment in works of human skill of the beauty that is diffused through all the works of Nature? And that beauty lies not merely in the bulk of objects, nor on their surface, but is as manifest in every part and atom composing them as in the combined whole. It is in itself composite; the combination, not of lesser, but of minuter beauties. To imitate, to approach, we must attempt a like arrangement, in order to obtain the same exquisite result. And how, except through earnest and scientific study, can we attain the knowledge that shall enable us to discover the pathway leading towards perfection?"

The improvement of taste in the art of design is not one of the least important applications of botany. "From want of the knowledge of this science has arisen the anomalies observable in figured patterns, in painted and carved furniture, in paper-hangings, and in dresses. These offend the chastened and classic eye of taste, and the incongruity will leave its impress though the individual be ignorant of botany. It is no uncommon thing to see the flower of one plant combined with the leaves of another, and perhaps associated with the stem of a third; or they may be the sorry creation of a morbid imagination, which sets the laws of harmony at defiance. Crabbe, in his evidence before a Committee of the House of Commons in relation to the question, expressly assigned this as one of the chief causes of the superiority of our continental neighbours. The French copy diligently from nature, and where can they get finer forms? Hence the chaste elegance of their patterns, and the superiority of their artificial flowers. Would the rosebud or blossom look so fair and lovely on the stem of a lily as on its native twig? or would the amaryllis appear so graceful if perched on the rose as it does in nature? There is a harmony and congruity in nature which we would do well to copy. It would correct the taste, and would supply the mind with images alike elegant and graceful."

"The real genius in the art of designing," it has been remarked, "does not puzzle his brain to invent strange forms to transfer to the fabric of the loom: he studies nature on the heath, in the field, the hedge-row, the garden, and the conservatory; and endeavours to combine the natural beauties which delight his eye and please his taste. The French designer, so pre-eminent in the beauty of his conceptions and the artistic excellence of his execution, no longer racks his mind for new forms, no longer studies the painted screens of India, or the elaborately ornamented porcelain of China, but flies to the Jardin des Plantes, and watches the development of the buds and foliage of the rare and beautiful plants which are there collected from all parts of the world. And such, too, is rapidly becoming the case in this country. Look at the beautiful forms which are so exquisitely delineated from time to time in the Art-Union, and in our schools of design, and see how very often pure nature is had recourse to. And to what better school can the artist go? Forms more elegant he cannot invent, colours more beautiful he cannot compound, and the supply thus offered is inexhaustible. The ancients availed themselves of it in all their studies of high art; the pillars of their temples were indebted for their enrichment to the beautiful foliage of plants; the elegance of their domestic utensils is attributable to their nice appreciation of floral beauties. The corollas of the various species of heath, hyacinth, harebell, etc., furnished them with models for their inimitable vases and amphoræ; and the interior walls of their dwellings were adorned with encaustic paintings, in which groups of flowers or floral borders were of almost constant occurrence. We admire their taste, and have long tried in vain to imitate it, but it is only now that our eyes are becoming opened to the sources from whence they drew their inspirations; and these being discovered, we may now hope for better things. One of the most eminent of French designers, in an article published in the *Art-Union,* states that the best of his designs were obtained from the conservatory."

V.—GENERAL REMARKS ON THE PHYSIOGNOMY OF VEGETATION.

We have thus endeavoured to lay before the reader, in a cursory way, the mode in which the science of botany ought to be prosecuted, and some of the advantages to be derived from the study of it. It is a science calculated to give pleasure to every mind. Though relating to living and organised beings, the prosecution of it calls for no cruel experiments, nor for any researches which could excite feelings of disgust even in the most sensitive heart. It is a study which can be turned to account in every situation, whether in the closet or in the field, on the highway or on the hillside, on the cultivated plain or in the wild mountain glen. Every flower on which we tread becomes a useful object of contemplation, and a means of pleasing recreation even amidst the cares and toils of life. "Flowers are not trifles, as one might know if he would only think how much pains God has taken with them everywhere; not one unfinished; not one bearing the marks of brush or pencil. Fringing the eternal borders of mountain winters; gracing the pulseless breast of the old grey granite; everywhere they are harmonising." The pleasure to be derived from this science is not confined to any period of life, nor to any rank of society. "In youth, when the affections are warm and the imagination vivid; in more advanced life, when sober judgment assumes the reins; in the sunshine of fortune, and the obscurity of poverty, it can be equally enjoyed. The opening buds of spring; the warm, luxuriant blossoms of summer; the yellow bower of autumn; and the leafless, desolate groves of winter, equally afford a supply of mental amusement and gratification to the botanist."

To the admirer of natural scenery, plants possess powerful attractions. Without them the landscape losses all its charms, and their presence gives beauty to objects, which would otherwise attract little notice. "Even the miserable hovel becomes picturesque when overspread with the foliage of the vine; the ruins of former magnificence acquire more reverence, and command a double share of our respect, when seen through the tracery of the ivy; and the horrors of the frowning rock are softened into beauty when mantled with pendent creepers or with alpine shrubs. The ivy-tendril, pendent from the orient window of the ancient ruin, lightly defined in the ray which it excludes, twining with graceful ease round some slender shaft, or woven amid the tracery of the florid arch, contributes in no small degree to give embellishment and interest to the ruin."

The love of flowers and of rural scenery is inherent in the constitution of man; and when deprived of the means of gratifying his taste in this respect, we see him adopting various expedients to supply the want.

"What are the casements lined with creeping herbs,
The prouder sashes fronted with a range
Of orange, myrtle, or the fragrant weed,
The Frenchman's darling? Are they not all proofs
That man, immured in cities, still retains
His inborn inextinguishable thirst
Of rural scenes, compensating his loss
By supplemental shifts, the best he may.
. . . .
. . . . There the pitcher stands
A fragment, and the spoutless teapot there;

> Sad witnesses how close-pent man regrets
> The country; with what ardour he contrives
> A *peep* at nature, when he can no more."

A garden presents many points of interest, and is associated with some of the most important events which have taken place on the earth. A garden was the habitation of our first parents in their state of innocency. "The Lord God planted a garden eastward in Eden; and there he put the man whom he had formed," telling him "to dress it and keep it" (Gen. ii. 8, 15). A garden was the place where Christ often retired with His disciples for meditation and prayer (John xvii. 1, 2). When man yielded to the tempter, it was in a garden. There the curse was pronounced; and there, too, the Redeemer was promised, who was to bruise the head of the serpent (Gen. iii. 15). It was also in a garden where the promised Messiah agonised under the withdrawal of His Father's face, when He was about to be betrayed into the hands of sinners, and to suffer the just for the unjust, that He might bring sinners unto God (Matt. xxvi. 36-46). The similitude of a garden is often used to represent the people of God (Song of Solom. iv. 12; v. 1), who are His husbandry (1 Cor. iii. 9), and the trees of His planting (Isa. lxi. 3).

Flowers form one of the first delights of early age, and they have proved a source of recreation to the most profound philosophers. Some of the greatest men both of ancient and modern times have been lovers of a garden. When man came forth from the hand of his Maker, a garden was selected as the fittest scene for a life of happiness. With the descriptions given, even by heathen writers, of a state of bliss, gardens have been often associated. The Elysian fields of the polished Greeks and Romans, and the Paradises of other nations, bear witness to this. The emblems and badges of nations and clans are frequently derived from the vegetable kingdom. The poet was crowned with laurel, and peace was marked by the olive branch. The groves of Academus were the resort of the Grecian philosophers; and under the sacred trees of India the benighted heathen worship their idols. Even our cemeteries are converted into gardens, and their gloom is enlivened by the beauteous flowers which blossom around; while the lesson is read, "Man that is born of a woman, is of few days, and full of trouble. He cometh forth like a flower, and is cut down" (Job xiv. 1, 2).

There is thus a natural taste for the enjoyment to be derived from the vegetation which covers the earth. Would that this taste had always been properly controlled and directed, so as to ensure man's comfort and true happiness! "Truly God gave us a sort of great enjoyment when He made the wild flowers so plentiful, and when He gave them to man as common things. If we wander by the stream, listening to its soft music, there we find them clustering on its surface, or crowding among the verdant sedges and grassy banks through which it flows. White crowfoots lie in patches, and rich blue forget-me-nots peep up among the waters; and the tall yellow-iris waves like a banner; and brooklimes, and water-violets, and water-cresses show their blue, and lilac, and snowy blossoms. On the banks the yellow flowers of the silver-weed glisten among the grey-green leaves; and the sweet odour of the queen-of-the-meadows is wafted far away over the land, like a sweet strain of melody."

How interesting are the associations connected with the practical prosecution of botany! Those who have joined in botanical excursions will appreciate the feelings of delight with which the floral treasures of the plain or of the mountain are gathered. "There is," says Dr George Johnston, "a preordained and beneficial influence of external nature over the constitution and mind of man. He who made nature all beauty to the eye implanted at the same time in His rational creatures an instinctive perception of that beauty, and has joined with it a pleasure and enjoyment that operate through life. You have a proof of this in the gaiety of the infant swayed only by external influences,—in the child's love of the daisy and the enamelled fields,—in the girl's haunt by the primrose bank and rushy brook,—in the schoolboy's truant steps by briery brake or flowery shaw, by trouting streams or nutting wood,—in the trysting tree and green leaves of love's age,—in the restless activity that sends us adrift in search of the picturesque,—in the 'London pride' of the citizen,—in the garden of retired leisure,—in the prize flower that lends its interest to old age. We are all the better for our botanical walks, when undertaken in the right spirit; they soothe, soften, or exhilarate. The landscape around us becomes our teacher, and from its lesson there is no escape; we are wooed to peace by the impress of Nature's beauty, and the very air we breathe becomes a source of gratification and pleasure."

In giving an account of a botanical trip to

Braemar, Clova, and other parts of the Scottish Highlands, I have elsewhere made the following remarks: *—Excursions may be truly said to be the *life* of the botanist. They enable him to study the science practically, by the examination of plants in their living state, and in their native localities; they impress upon his mind the structural and physiological lessons he has received; they exhibit to him the geographical range of species, both as regards latitude and altitude; and with the pursuit of scientific knowledge, they combine that healthful and spirit-stirring recreation which tends materially to aid mental efforts. The companionship, too, of those who are prosecuting with zeal and enthusiasm the same path of science, is not the least delightful feature of such excursions. The various phases of character exhibited, the pleasing incidents that diversified the walk, the jokes that passed, and even the very mishaps or annoyances that occurred,—all become objects of interest, and unite the members of the party by ties of no ordinary kind. And the feelings thus excited are by no means of an evanescent or fleeting nature; they last during life, and are always recalled by the sight of the specimens which were collected. These apparently insignificant remnants of vegetation recall many a tale of adventure, and are associated with the delightful recollection of many a friend. It is not indeed a matter of surprise, that those who have lived and walked for weeks together in a Highland ramble, who have met in sunshine and in tempest, who have climbed together the misty summits, and have slept in the miserable shieling, or under the shelter-stone—should have such scenes indelibly impressed on their memory.

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* Jameson's Edinburgh New Philosophical Journal, July 1848.

There is, moreover, something peculiarly attractive in the collecting of *alpine* plants. Their comparative rarity, the localities in which they grow, and frequently their beautiful hues, conspire in shedding around them a halo of interest far exceeding that connected with lowland productions. The alpine Veronica, displaying its lovely blue corolla on the verge of dissolving snows; the Forget-me-not of the mountain summit, whose tints far excel those of its namesake of the brooks; the Woodsia, with its tufted fronds adorning the clefts of the rocks; the nival Gentian, concealing its eye of blue in the ledges of the steep crags; the alpine Astragalus, enlivening the turf with its purple clusters; the Lychnis, choosing the stony and dry knoll for the evolution of its pink petals; the alpine Sowthistle, raising its stately stalk and azure heads in spots which try the enthusiasm of the adventurous collector; the pale-flowered Oxytropis, confining itself to a single British cliff; the Azalea, forming a carpet of the richest crimson; the Saxifrages, with their white, yellow, and pink blossoms clothing the sides of the streams; the Saussurea and Erigeron, crowning the rocks with their purple and pink capitula; the pendent Cinquefoil, blending its yellow flowers with the white of the alpine Cerastiums and the bright blue of the stony Veronica; the stemless Silene, giving a pink and velvety covering to the decomposing granite; the yellow Hieracia, whose varied transition-forms have furnished such a fertile cause of dispute among botanists; and "other glorious flowers, which look as if their hues had been wrung for evening skies;" the slender and delicate grasses, the chickweeds, alsine and sagina, the carices, and the rushes, which spring up on the moist alpine summits; the graceful ferns; the tiny mosses, with their urnlike thecæ; the crustaceous dry lichens, with their spore-bearing apothecia,—all these add a charm to botanical excursions, impressing them indelibly on the memory, and associating them with objects of the most pleasing nature.

We have already attended to the beautiful tints displayed in the colours of flowers, and the skill with which they are arranged; we would now notice the regular succession in which flowers make their appearance, as indicating another wise provision of our Creator. As Cicero remarks, "Neque ea uno tempore anni; ut semper et novitate delectemur et copia" (De Nat. Deor. ii. 53). How interesting and instructive to trace the floral productions of the seasons, from the early buds and flowers of spring to the withered stems and the lifeless boughs of winter! How does the voice of spring call us to contemplate the wonder-working Jehovah! "A few months ago," Gaussen remarks, "and the earth was a desert of ice: all was silent and lifeless. The plants were dry, and their beauty gone; everywhere they presented to us only the aspect of death. The trees stripped of their foliage, like dry bones, rattled their bare branches against each other; the brooks and torrents were arrested in their course; their motion was suspended; instead of the breath of life which animates them to-day, the north wind, like the breath of destruction, swept along over that vast cemetery.

Who of us, if custom had not rendered us familiar with the prodigies of spring, would not, at the sight of all that death, have been tempted to exclaim, Lord, can all these things live again? And yet what have we seen! From the first days of spring the Almighty has prophesied upon these dry bones; they have appeared to move, to be covered as it were with the nerves of life. Now they live, and they seem to be an exceeding great army to the praise of God. Has not a spirit of resurrection, a living soul, entered into nature? Has not the breath of God, from the four winds, breathed upon these dry bones? Each succeeding day these miracles of resurrection increase and spread with as much rapidity as splendour. The whole creation, as if raised from a tomb, is penetrated with life, and pulsates with joy. All these marvels preach to us the truth and certainty of the Divine promises. They repeat, in a manner most impressive, that the day is coming when the earth, hitherto cursed, shall see rising upon it the sun of an eternal spring."

The revival of alpine vegetation is thus referred to by a writer in "Excelsior," as illustrated by the alpine vernal gentian of gorgeous blue:—

THE ALPINE GENTIAN.

"She 'neath ice-mountains vast
Long had lain sleeping
When she looked forth at last
Timidly peeping.

Trembling she gazed around,—
All around her slept,
O'er the dead icy ground
Cold shadows crept.

Mournfully pondering,
Gazed she on high;
White clouds were wandering
Through the blue sky.

There smiled the kindly sun,
Gentle beams kissed her;
On her the mild moon shone
Like a saint sister.

There twinkling many a star
Danced in sweet mirth;
The warm heavens seemed nearer far
Than the cold earth.

So she gazed steadfastly
Loving on high,
Till she grew heavenly
Blue as the sky;

And the cold icicles
Near which she grew,
Thawed in her skyey bells.
Fed her with dew:

And the tired traveller
Gazing abroad,
Fixing his eyes on her,
Thinketh on God,—

Thinks how, 'mid life's cold snow,
Hearts to God given,
Breathe out, where'er they go,
Summer and heaven."

Flowers do not appear all at once, but in orderly rotation. "The snowdrop, foremost of the lovely train, dressed in its robe of innocency, breaks its way through the frozen soil long before the trees have ventured to unfold their leaves, and even while the icicles are pendent on our houses ; next peeps out the crocus, but cautiously and with an air of timidity ; nor is the violet last in this shining embassy of the year, which, with all the embellishments that would grace a royal garden condescends to line our hedges, and to grow at the feet of briars. The polyanthus, after adorning the border with its sparkling beauties, gives place to the auricula, with its eye of crystal and robe of the most glossy satin. Tulips then begin to raise themselves on their stately stalks, and adorn the parterre with the gayest colours." In succession appear the anemone, ranunculus, and carnation, to add fresh beauty to the scene. It is in vain to attempt to enumerate the varied flowery forms which succeed each other in the garden. There is an endless multiplicity in their character, yet an invariable order in their approaches. Every month, every week, has its peculiar ornaments; not servilely copying the works of its predecessor, but forming and executing some new design—so lavish is the fancy, yet so exact is the process of nature.

"Spake full well, in language quaint and olden,
One who dwelleth by the castled Rhine,
When he called the flowers, so blue and golden,
Stars, that in earth's firmament do shine.

Stars they are, wherein we read our history,
As astrologers and seers of eld;
Yet not wrapped about with awful mystery,
Like the burning stars which they beheld.

Wondrous truths, and manifold as wondrous,
God hath written in those stars above;
But not less in the bright flow'rets under us
Stands the revelation of His love.

Bright and glorious is that revelation,
Written all over in this great world of ours;
Making evident our own creation
In these stars of earth,—these golden flowers.

And the poet, faithful and far-seeing,
Sees, alike in stars and flowers, a part
Of the self-same, universal Being,
Which is throbbing in his brain and heart.

Gorgeous flowers in the sunlight shining,
Blossoms flaunting in the eye of day,
Tremulous leaves, with soft and silver lining,
Buds that open only to decay;

Brilliant hopes, all woven in gorgeous tissues,
Flaunting gaily in the golden light;
Large desires, with most uncertain issues,
Tender wishes, blossoming at night!

These in flowers and men are more than seeming;
  Workings are they of the self-same Power,
Which the poet, in no idle dreaming,
  Seeth in himself and in the flower.

Everywhere about us are they glowing,
  Some, like stars, to tell us Spring is born;
Others, their blue eyes with tears o'erflowing,
  Stand, like Ruth, amid the golden corn.

Not alone in Spring's armorial bearing,
  And in Summer's green-emblazoned field,
But in arms of brave old Autumn's wearing,
  In the centre of his brazen shield;

Not alone in meadows and green alleys,
  On the mountain-top, and by the brink
Of sequestered pools in woodland valleys,
  Where the slaves of nature stoop to drink;

Not alone in her vast dome of glory,
  Not on graves of bird and beast alone,
But in old cathedrals high and hoary,
  On the tombs of heroes, carved in stone;

In the cottage of the rudest peasant,
  In ancestral homes, whose crumbling towers,
Speaking of the Past unto the Present,
  Tell us of the ancient games of flowers.

In all places then, and in all seasons,
  Flowers expand their light and soul-like wings,
Teaching us by most persuasive reasons,
  How akin they are to human things.

And with childlike, credulous affection,
  We behold their tender buds expand;
Emblems of our own great resurrection,
  Emblems of the bright and better land."

Longfellow.

We ought never to forget, that we may look on the broad landscape smiling in summer beauty, and speak with delight of the wonders of nature, and the goodness of a beneficent God, and follow with reverence the man of science as he displays God's wisdom and power in the creation of the universe; and yet there may be no true appreciation of the character of God, no sense of his holiness, and none of that wisdom which cometh from above (James iii. 17). "Where shall wisdom be found? or where is the place of understanding? Man knoweth not the price thereof; neither is it found in the land of the living. The depth saith, It is not in me; and the sea saith, It is not with me. It cannot be gotten for gold, neither shall silver be weighed for the price thereof, for the price of wisdom is above rubies. Behold the fear of the Lord, that is wisdom; and to depart from evil is understanding" (Job xxviii. 12-18, 28).

The study of the economy of vegetation in all its bearings makes the devout mind exclaim in wonder and praise, "O Lord, how manifold are thy works! in wisdom hast thou made them all; the earth is full of thy riches" (Ps. civ. 24). "The works of the Lord are great, sought out of them that have pleasure therein" (Ps. cxi.

2). The more we examine into all God's ways and doings in providence and grace, the more are we led to see the force of the apostle's statement,—"O the depth of the riches both of the wisdom and knowledge of God! how unsearchable are His judgments, and His ways past finding out!" (Rom. xi. 33).

> "So He ordained, whose way is in the sea,
> His path amidst great waters, and His steps
> Unknown;—whose judgments are a mighty deep,
> Where plummet of archangel's intellect
> Could never yet find soundings, but from age
> To age let down, drawn up, then thrown again,
> With lengthen'd line and added weight, still fails;
> And still the cry in Heaven is, 'O the depth!'"

The further that science extends the better it enables us to see everywhere wonderful contrivance and a beautiful adaptation of means to ends; the more it gives us the means of observing that wisdom which has devised and which sustains all around us; and the more powerfully does it impel us to admiration and worship, and to exclaim with our great poet:—

> "These are thy glorious works, Parent of good,
> Almighty; thine this universal frame,
> Thus wondrous fair; thyself how wondrous then!
> Unspeakable, who sitt'st above the heav'ns,
> To us invisible, or dimly seen
> In these thy lowest works; yet these declare
> Thy goodness beyond thought, and power divine."

The contemplation of God's handiwork, whether displayed in the starry heavens, where He hath set a tabernacle for the sun, or in those stars of the earth—the flowers—should ever, as in the case of the Psalmist, be accompanied by the heartfelt conviction that "The law of the Lord is perfect, converting the soul: the testimony of the Lord is sure, making wise the simple: the statutes of the Lord are right, rejoicing the heart: the commandment of the Lord is pure, enlightening the eyes: the fear of the Lord is clean, enduring for ever: the judgments of the Lord are true and righteous altogether" (Ps. xix. 7-9).

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